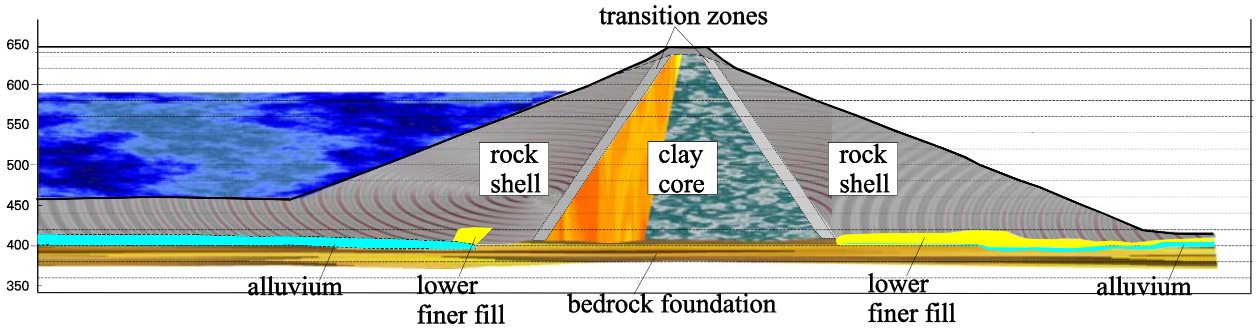
January 2011

2010 SURVEILLANCE REPORT
December 2009 through December 2010
LEROY ANDERSON DAM NO. 72-9
Santa Clara County



Santa Clara Valley
Water District

Santa Clara Valley
Water District SM

5750 ALMADEN EXPWY
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January 13, 2011

Mr. David A. Gutierrez, Chief
Division of Safety of Dams
Department of Water Resources
1416 Ninth Street
P.O. Box 942836
Sacramento, CA 94236-0001

Subject: Leroy Anderson Dam, No. 72-9, Santa Clara County
December 2009 Through December 2010
2010 Surveillance Report

Dear Mr. Gutierrez:

Please find enclosed two copies of our 2010 surveillance report for Leroy Anderson Dam covering the period from December 2009 to December 2010.

The surveillance data from Anderson Dam and the Santa Clara Valley Water District's (District) field observations confirm acceptable performance of the dam for the period of this report, with the dam showing normal responses to the environment, aging process, and external events. During the period of this report, there were no surveillance instrumentation alarm conditions. The District will continue with the current monitoring program and safety inspections, and will keep Division of Safety of Dams (DSOD) informed of any significant changes pertaining to the surveillance or performance of Leroy Anderson Dam.

An operating restriction for Anderson Reservoir to provide more than approximately 57 feet total freeboard was implemented in October 2010 under the approval of DSOD and concurrence of FERC. The restriction is monitored by District Operations Planning Analysis Unit. This operating restriction was implemented to provide an added margin of safety in response to preliminary seismic stability results for Anderson Dam. Except for the new operating restriction at Anderson Reservoir, there are no substantive changes in dam or reservoir response compared to previous years.

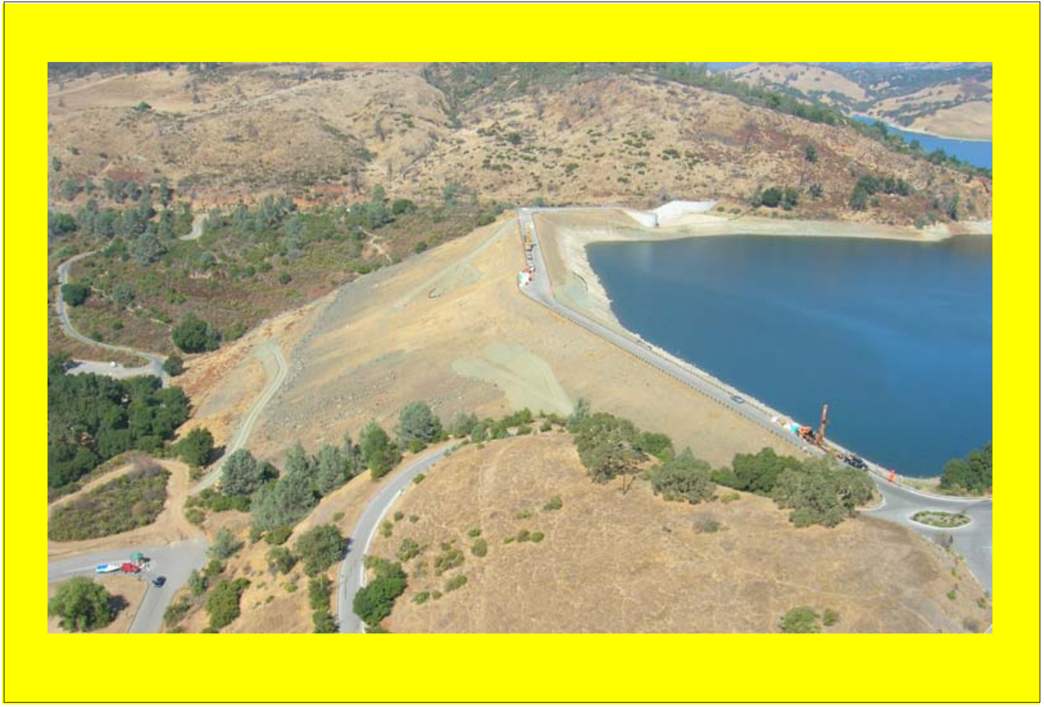
Please contact me at (408) 265-2607, extension 2736, if you have any questions.

Sincerely,

James M. Fiedler, P.E., D.WRE
Chief Operating Officer
Water Utilities Enterprise

Enclosures
cc/enc: F. Makdisi, AMEC Geomatrix
C. Hunt, Geosyntec
F. Maitski, D. Hook, M. Mooers, B. Baker, S. Wu, J. Nelson, Library (4)
cc: R. Jacobs, D. Hook, L. Lopez
jn:fd
0110a-l.docx

2010 SURVEILLANCE REPORT
December 2009 through December 2010
LEROY ANDERSON DAM NO. 72-9
Santa Clara County



Date of photo 10/10/06
Photo shows temporary drill rig access roads and 2 drill rigs on dam crest for DIP

Prepared for:

State of California
Department of Water Resources
Division of Safety of Dams
P.O. Box 942836
Sacramento, CA 95236

Prepared by:
Santa Clara Valley Water District
5750 Almaden Expressway
San Jose, CA 95118

January 2011

2010 SURVEILLANCE REPORT
December 2009 through December 2010
LEROY ANDERSON DAM NO. 72-9
Santa Clara County

The analysis and interpretation of the instrumentation and other relevant data presented in this report has involved the application of certain graphical and statistical interpretive techniques common to the geosciences and earth dam engineering professions. The conclusions presented in this report were developed upon evaluating the performance of all instruments and other pertinent data during the specified period, and represent the professional judgment of its author. This report was published on January 10, 2011.

Report prepared by:

PROFESSIONAL GEOLOGIST
JAMES LEWIS NELSON
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CERTIFIED ENGINEERING GEOLOGIST
STATE OF CALIFORNIA

James L. Nelson, C.E.G.
Senior Engineering Geologist
Dam Safety Program Unit

Quality Control/Quality Assurance

This report has been reviewed and approved for publication by the undersigned professional engineers. I attest and confirm that the report was prepared by the individual who signed the report under my immediate direction and supervision and that the conclusions and recommendations presented herein are reasonable and supported by District management.

Reviewed and approved by:

Dave E. Hook

David E. Hook, P.E.
Engineering Unit Manager
Dam Safety Program Unit

REGISTERED PROFESSIONAL ENGINEER
STEVEN M. WU
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STATE OF CALIFORNIA

Reviewed by:

Steven M. Wu

Steven M. Wu, P.E., G.E.
Senior Engineer
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1.0 EXECUTIVE SUMMARY

This 2010 Surveillance Report summarizes the Santa Clara Valley Water District's (District) evaluation of Leroy Anderson Dam (Anderson Dam) No. 72-9 and reservoir located in southern Santa Clara County, California, for the surveillance period from December 1, 2009 through December 31, 2010. Our review of the surveillance data and our periodic safety inspections indicate that Anderson Dam and appurtenant structures appear to show normal response to their environment, aging process, and external events. Except for a second operating restriction mentioned below, there were no major incidents or changes at the dam during 2010. During the period of this report, there were no surveillance instrumentation alarm conditions.

The District will continue with the current monitoring program and safety inspections and will keep DSOD informed of any significant changes pertaining to the surveillance or performance of Anderson Dam. During the current reporting period, there were no new activities at the site that would impact monitoring of this facility.

An operating restriction for Anderson Reservoir to provide ~57 feet of total freeboard was implemented under the approval of the Division of Safety of Dams (DSOD) and the concurrence of FERC. The restriction is monitored by District Operations and Analysis Unit beginning in October 2010 and supersedes the earlier January 2009 restriction. This operating restriction was implemented to provide an added margin of safety in response to preliminary seismic stability results for Anderson Dam. Except for the new operating restriction at Anderson Reservoir, there are no substantive changes in dam or reservoir response compared to previous years.

2.0 INTRODUCTION

2.1 Scope and Purpose

As discussed in *Section 2.2 New Report Format*, this surveillance report follows a new format that is intended to streamline report preparation and review.

The focus of this 2010 annual surveillance report is to review the data for overall accuracy and to make assessments of general data trends. If any significant geotechnical or operational events have occurred (i.e., earthquakes, sustained elevated reservoir levels, significant operational or maintenance changes, or dam instrumentation/monitoring changes), these are addressed to the appropriate level in this report. This report provides historic data plots covering the last 10 years (since ~ 2000) or since the installation date if less than ten years of instrument readings. The reader is referred to previous reports for earlier observations.

This report addresses comments regarding surveillance reporting from the last field inspection reports for Leroy Anderson Dam facilities by DSOD titled “Inspection of Dam and Reservoir in Certified Status” dated October 21, 2009 (DSOD, 2009) for a DSOD inspection of that facility. The DSOD report summarized findings of an annual DSOD inspection that occurred on October 6, 2009. According to their latest inspection report and review of the 2009 surveillance report (Nelson, 2009), DSOD stated that “Based on submitted data, the embankment is performing satisfactorily. No additional instrumentation is judged necessary at this time.” DSOD did not provide any specific comments regarding deficiencies in the District’s instrumentation surveillance reporting of Leroy Anderson Dam.

2.2 New Report Format

This report follows a new format that facilitates evaluation of the data and interpretations by combining all aspects of instrumentation information for each instrument group. The new format eliminates separate sections of previous reports that consisted of background information on each instrument group, data for each instrument group, and separate data plots at the end of the report. In the current format all related information for a particular instrumentation group (background, data, and data plots) are combined into one section. All pertinent text related to a particular instrumentation group are combined and included on 1 to 2 pages. To further ease review of the text relative to the data, the accompanying data plots are shown immediately opposite the text. The goal is to succinctly present the written and graphical information from each surveillance item together as a stand-alone-section within the report. To accommodate the new format with text on one page and pertinent data plots on the opposite page requires that some pages be intentionally left blank.

2.3 Recent Instrumentation and Safety Studies

2.3.1 Seismic Safety Evaluation – Preliminary & SSE1A

Currently, the District's geotechnical consultant AMEC Geomatrix (AMEC) is finalizing their analysis and summary report for a full seismic stability evaluation (SSE1A) of Anderson Dam that will supersede their preliminary report (AMEC, 2008) and provide an in-depth assessment of seismic stability. The SSE1A work also includes a detailed seismotectonic study by Fugro William Lettis Associates (FWLA) for all District Dams included as an attachment to a report by AMEC (2009a). The originally planned exploration and laboratory testing phase of work of the SSE1A for the embankment is complete, which will be followed by analyses and a final report by May 2011. At the time of this surveillance report the District had received the draft SSE1A report for review (AMEC, 2010). Preliminary results including drill hole logs and well construction sheets of the two new open well piezometers (OW-2 and OW-3) are summarized in the AMEC draft report (2010). Pertinent findings of SSE1A with respect to dam safety surveillance are included in this surveillance report. The District will continue to keep DSOD informed and involved regarding the SSE1A study results for Anderson Dam.

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3.0 BACKGROUND INFORMATION AND METHODOLOGY

3.1 General Surveillance

Figure 1 shows the locations of crest monuments, spillway training wall monuments, pneumatic, vibrating wire and open well piezometers, accelerometers, and the spillway underdrain weirs at Anderson Dam. Transverse and longitudinal sections are shown in Figures 2 through 4. Specifically, Figure 2 presents a transverse cross section A-A’ through a minor section of the left abutment of the dam. Figure 3 presents cross section B-B’ near the maximum section of the dam. Figure 4 presents a longitudinal section C-C’ along the crest. The sections show vibrating wire piezometers, pneumatic piezometers, open well piezometer OW-1, and open well piezometers OW-2 and OW-3 installed during the current Seismic Stability Evaluation (SSE1A).

Table 1 (page 8) presents a list of locations for each vibrating wire piezometer (VWP) and open well piezometers OW-2 and OW-3. Table 2 (page 9) summarizes piezometric surface elevations (PSE in ft) of pneumatic piezometers and newer open well piezometers, and Table 3 (page 14) summarizes spillway underdrain flow. Tables 4 and 5 (pages 17 and 18, respectively) summarize survey data from the dam crest and spillway training walls. Table 6 (page 19) presents a list of pertinent data of each in-place inclinometer sensor (IPIs). All surveillance data are also shown graphically on Figures 5 through 13, and discussed later in the report.

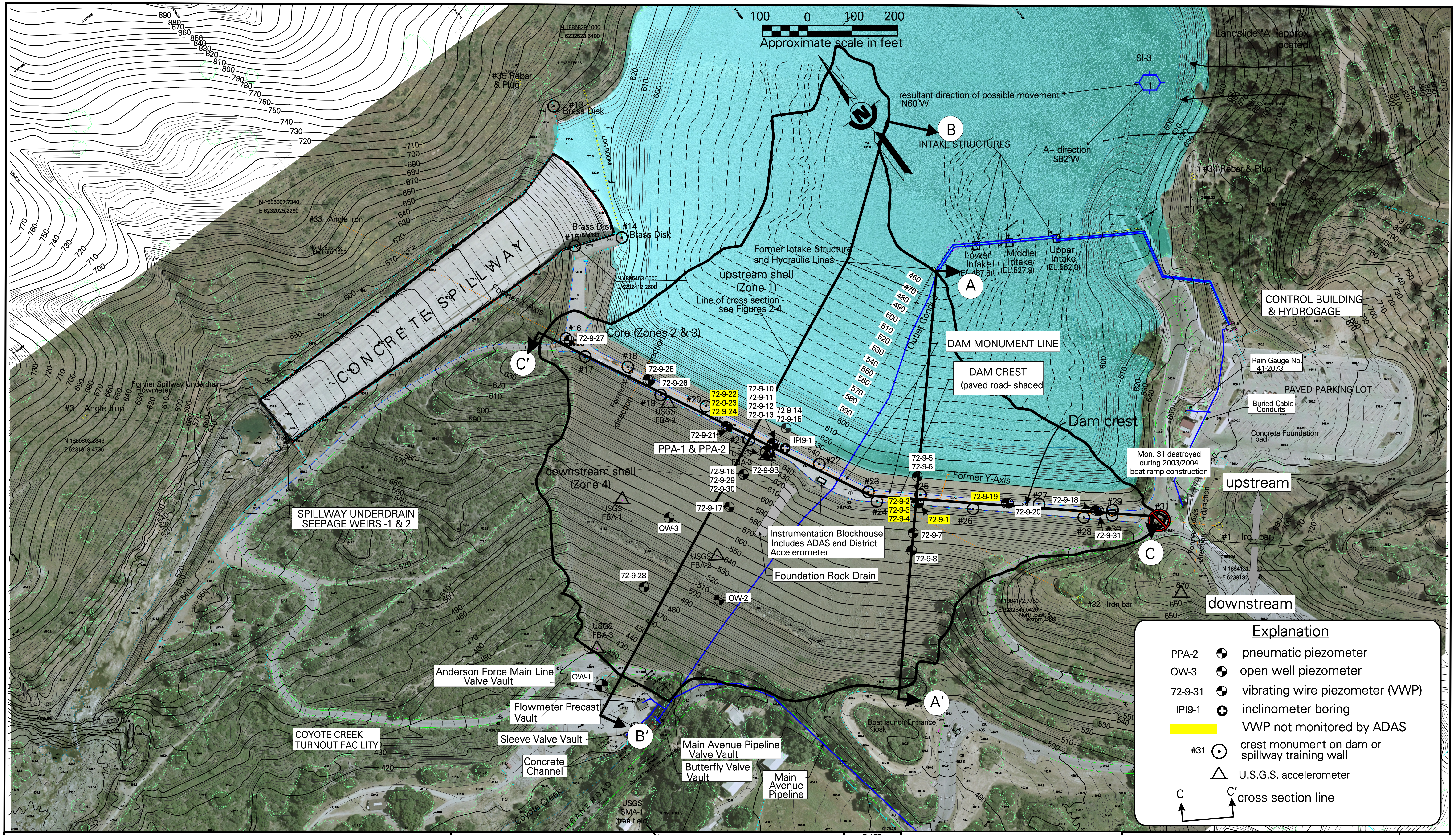
During the time period covered by this report, the District monitored 2 pneumatic piezometers in the dam, 2 spillway underdrain seepage weirs, 15 dam crest survey monuments, 2 spillway training wall survey monuments, 3 open well piezometers, 31 vibrating wire piezometers and 6 in-place inclinometer sensors.

All new data covered in this report is presented in tabular form, and plotted to facilitate review. For the period of this report, data were collected annually for survey monuments and monthly for pneumatic piezometers and underdrain weirs. Data were collected from the vibrating wire piezometers at various intervals as summarized in *Section 4.0 Surveillance Information*. Crest monuments were surveyed at the times indicated (typically near the end of every year).

All elevation data presented in this report have been adjusted for the current datum used by the District Dam Safety Program, which is the North American Vertical Datum (NAVD) 1988, which is 2.80 feet higher than the old datum, National Geodetic Vertical Datum (NGVD) 1929, at this location.

Data from vibrating wire piezometers and in-place inclinometers are collected by an Automated Data Acquisition System (ADAS), which was implemented in early December 2008. As explained below in *Section 4.7 In-place Inclinometer Sensors (IPIs)*, we have been collecting manual readings of the IPIs since September 16, 2008, because ADAS is not yet collecting viable IPIs data. We have also been collecting manual VWP readings from several piezometers that have power supply issues related to the solar panel and battery system.

During the period of this report, there have been minimal changes in reservoir elevations (total excursion of ~19 feet) and relatively low reservoir elevations (between ~24 and 50 feet below spillway lip). The maximum reservoir elevation achieved in May 31, 2010 of el. 604.2 ft was similar to the maximum reservoir elevation of 602 ft in 2009. In this report, vibrating wire piezometer plots are grouped and presented as standard piezometer and reservoir plots versus time.



Reference information and notes:

1) This map is a compilation of aerial mapping, survey field data, and digitized construction maps. Maximum error could be ± one foot vertical and horizontal; error greater for upstream topographic lines (see note 7)
2) Grid is based on California Coordinate System, Zone III, NAD 83.
3) Elevations based on N.G.S. Vertical datum, NAVD 88. The DE between NGVD 29 and NAVD 88 is 2.80′
4) Photogrammetric mapping: Transvision, Photo date 12/11/97; color photo date 2006
5) file W:\geology\DAMS\Historic Dam Geology\anderson\ANDHistgeo.cdr
6) selected 1987-88 dam raise values in feet shown in red
7) upstream dam topography (dashed lines) from as-built 1988 "Leroy Anderson Dam Intake Structure Modification, Sheet 2, scale 1"=100′, dated 1-8-88, from 10-7-87 aerial photography, modified to NGVD 88

DATE	12/16/10
DESIGN	JLN
DRAWN	JLN
CHECKED	DEH

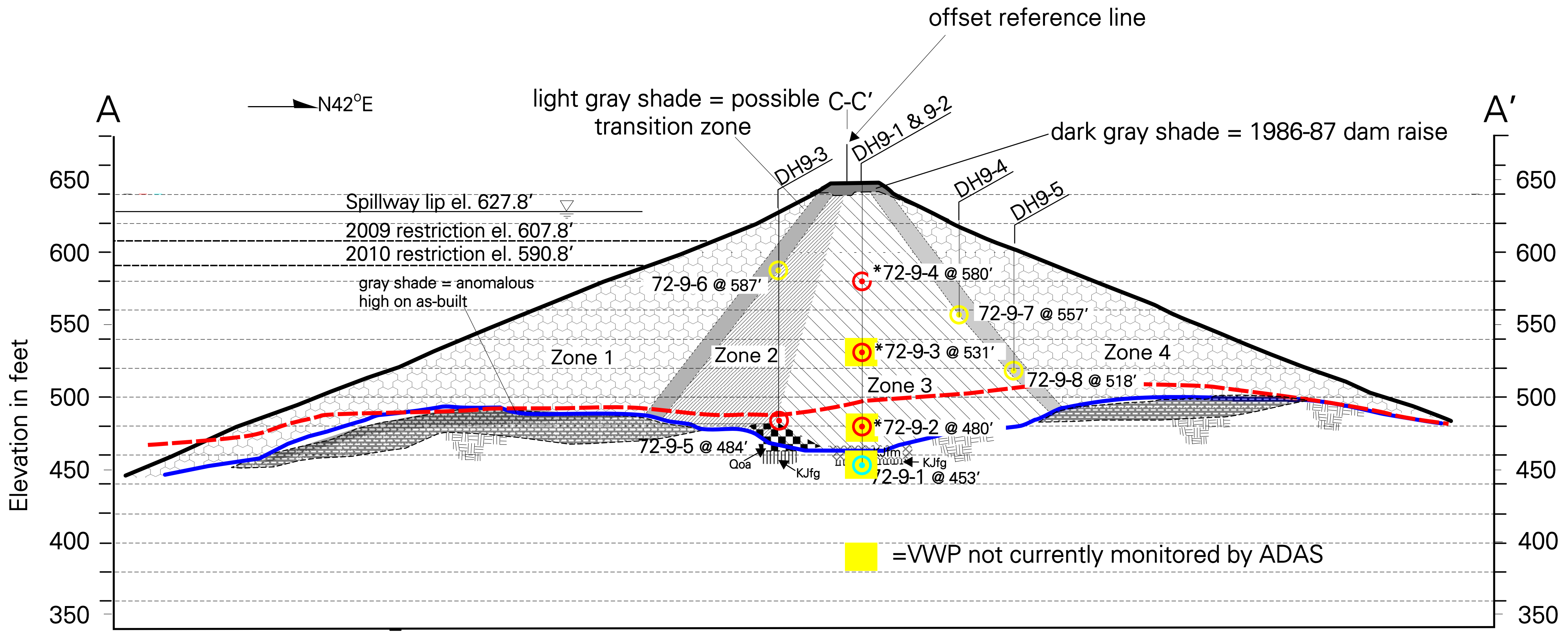
Santa Clara Valley Water District

Topographic Map
Surveillance Instrumentation
Leroy Anderson Dam

SCALE
1″ = 200′

PLATE
1

Section A-A′ (sta. 6+00)



Explanation

DH9-5 boring number

72-9-8 ⊙ vibrating wire piezometer

excavated topography (as-built) adjusted to DIP drill hole logs

excavated topography (as-built) adjusted 2.8′ for new datum

original topography adjusted 2.8′ for new datum

* = installed using grout-in methods (see text)
all other piezometers installed using sand-pack methods

Bedrock & Soil Foundation Units from DIP/SSE1B

▦ Qoa/Qc = Quaternary older alluvium and/or colluvium

▤ QTsc = Plio-Pleistocene Santa Clara Fm

▨ KJfm = Franciscan Complex melange

▥ KJfg = Franciscan Complex greenstone

⊙ red = embankment
⊙ yellow = transition zone
⊙ green = colluvium/alluvium
⊙ blue = foundation

Notes:
1) File: W:\geology\dams\Historic_Dam_Geology\Anderson\andxsecA-A′rev.cdr
2) basis of elevations is NAVD 1988-elevations are 2.80′ higher than NGVD 1929

DATE
11/04/09
DESIGN
JLN
DRAWN
JLN
CHECKED
DEH

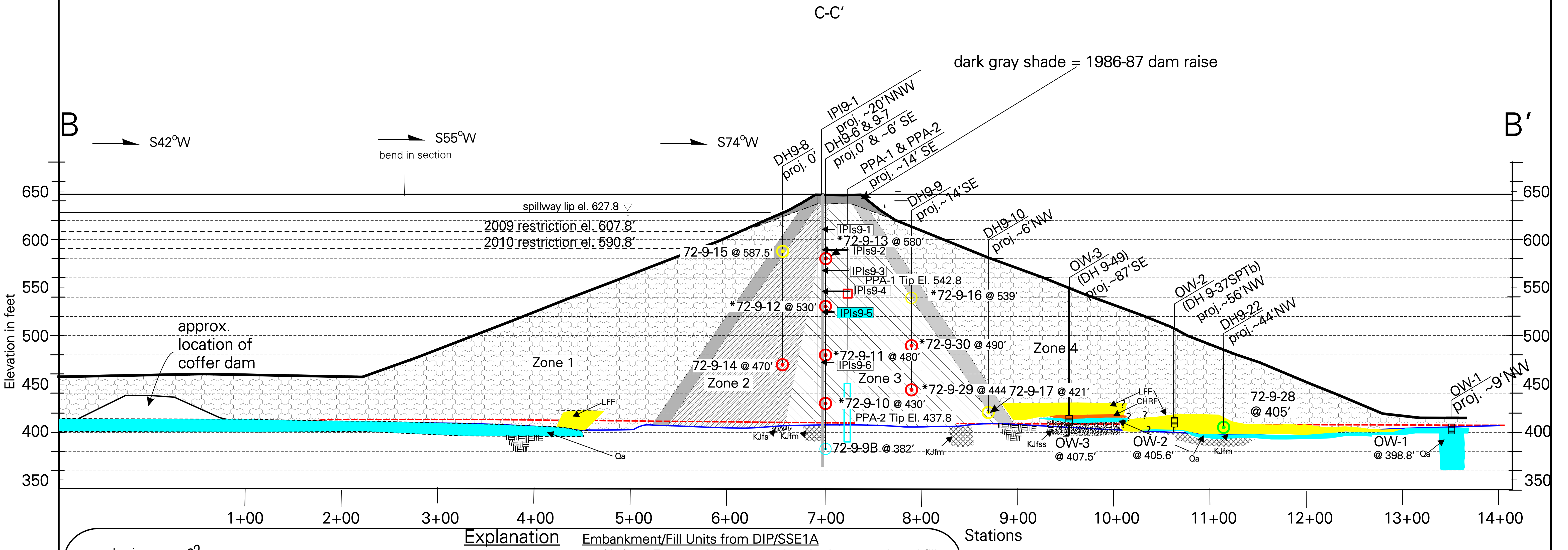
Santa Clara Valley Water District

Cross Section A-A′

Leroy Anderson Dam

SCALE
1″=100′
PLATE
2

Section B-B′ (transverse max section along thalweg)



Explanation

boring number DH9-22

72-9-28 ⊙ vibrating wire piezometer

72-9-ASI-2 automated slope indicator

DH9-20 geophysical

DH9-20 lithologic logging

excavated topography (as-built) corrected 2.8′ for new datum

excavated topography (as-built) adjusted to DIP drill hole logs

original topography corrected 2.8′ for new datum

* = installed using grout-in methods (see text)
all other piezometers installed using sand-pack methods

Embankment/Fill Units from DIP/SSE1A

- Zones 1 (downstream) and 4 (upstream): rockfill
- Transition Zones, downstream and upstream
- Zone 2 upstream core
- Zone 3 downstream core
- Construction haul road fill (CHRF)
- Lower Finer Fill (LLF), downstream and upstream

Bedrock and Foundation Soil Units from DIP/SSE1A

- Qa/Qc = Quaternary alluvium and/or colluvium
- KJfm = Franciscan Complex melange
- KJfss = Franciscan Complex graywacke sandstone
- ⊙ red = embankment
- ⊙ yellow = transition zone
- ⊙ green = colluvium/alluvium
- ⊙ blue = foundation

Notes:
1) File: W:\geology\dams\historic dam geology\anderson\andxsecB-B′rev.cdr
2) basis of elevations is NAVD 1988-elevations are 2.80′ higher than NGVD 1929
3) Downstream and upstream foundation materials taken from AMEC (2010 draft)

DATE
12/17/10
DESIGN
JLN
DRAWN
JLN
CHECKED
DEH

Santa Clara Valley Water District

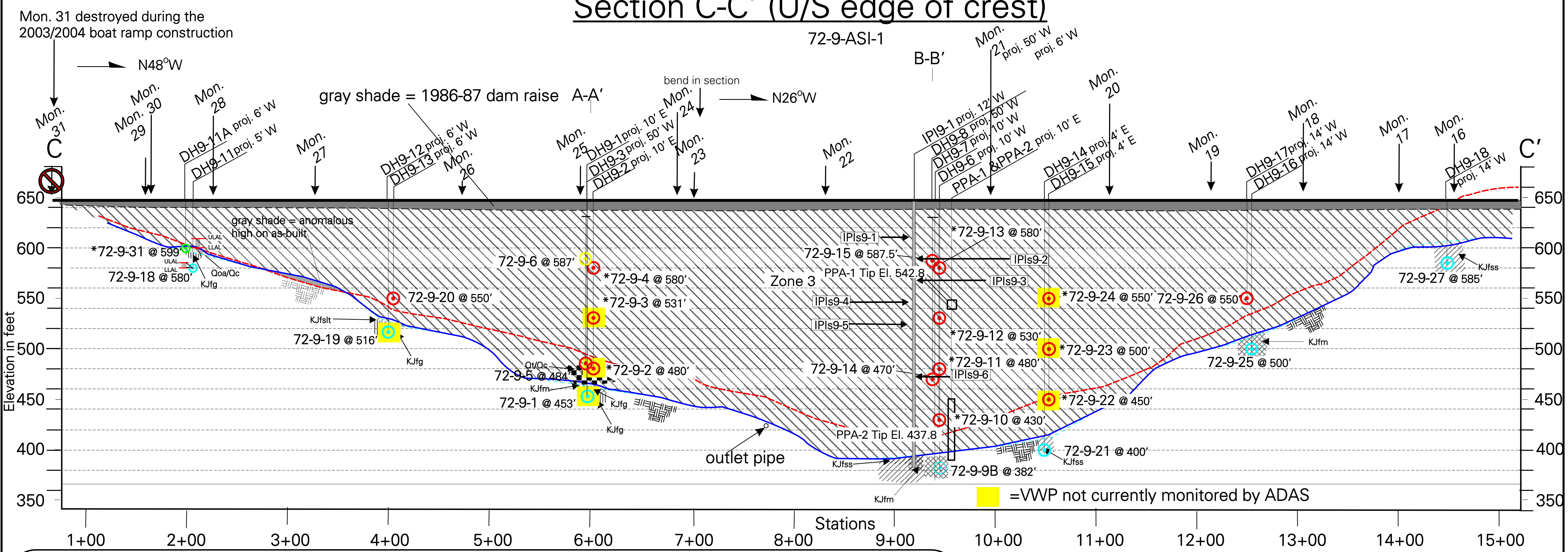
Cross Section B-B′

Leroy Anderson Dam

SCALE
1″=100′

PLATE
3

Section C-C′ (U/S edge of crest)



Explanation

boring number DH9-18

vibrating wire 72-9-27 ⊙ piezometer

72-9-ASI-2 automated slope indicator

DH9-20 geophysical/ lithologic logging

Bedrock and Foundation Soil Units from DIP

- ▦ Qoa/Qc = Quaternary older alluvium and/or colluvium
- ▩ KJfm = Franciscan Complex melange
- ▥ KJfg = Franciscan Complex greenstone
- ▨ KJfss = Franciscan Complex sandstone

- ------ excavated topography (as-built) corrected 2.8′ for new datum
- ------ original topography corrected 2.8′ for new datum
- —— excavated topography (as-built) adjusted to DIP drill hole logs

- ⊙ red = embankment
- ⊙ green = colluvium/alluvium
- ⊙ blue = foundation

* = installed using grout-in methods (see text)
all other piezometers installed using sand-pack methods

Notes:
1) File: W:\Geology\DAMS\Historic_Dam_Geology\Anderson\andxsecC-CDIP.cdr
2) basis of elevations is NAVD 1988-elevations are 2.80′ higher than NGVD 1929

DATE	12/17/10
DESIGN	JLN
DRAWN	JLN
CHECKED	DEH

Santa Clara Valley Water District

Longitudinal Cross Section C-C′

Leroy Anderson Dam

SCALE
1″=100′

PLATE
4

Reported rainfall is measured at District Rain Gauge No. 41-2073, which is located a few hundred feet southeast of the left abutment of Leroy Anderson Dam.

4.0 SURVEILLANCE INFORMATION

This report graphically depicts surveillance data as time-series plots of reservoir levels and rainfall (Figure 5), piezometers (Figures 6 through 8), spillway underdrain weirs (Figure 9), and crest and spillway training wall monument surveys (Figures 10 through 12).0

As part of our quality assurance/quality control, we routinely plot and review reservoir elevation data and piezometric surface elevation data (PSE) as two types of data plots. One involves plots of piezometer data versus time (time plots) and the other involves plots of reservoir elevation versus PSE data (cross plots). While both graphical forms help decipher trends, cross plots are specifically useful for tracking historic trends independent of time but relative to reservoir response. Visually, the cross plots allow for quickly evaluating whether a given data point is reasonable, is out of the norm and therefore a sign of potential adverse conditions if significantly different (higher or lower) than historic trends, or is possibly a spurious data point.

The cross plots (Appendix A) are more likely to show subtle piezometric responses relative to minor changes in reservoir elevations (if applicable) because there is a more direct correlation between piezometric response and reservoir fluctuations than plots showing piezometric data versus time. Figures A-1 through A-31 includes individual cross plots for the 31 VWPs. Other piezometers (open well and pneumatic) including the new piezometers OW-2 and OW-3 installed during SSE1B are shown in Figures A-32 through A-36. Figure A-37 shows a cross plot of the spillway underdrain weir discharge data. In addition to showing possible trends and responses, these plots graphically show piezometer tip elevation, ground surface elevation above the piezometer tip, and spillway lip elevations. Also shown are restrictions.

4.1 Brief Description of ADAS

This section provides a brief overview of the functionality of ADAS. The ADAS system involves multiple field measurement units that are networked together at the dam by wireless radio links at the approximate surface location of each field instrument or grouped instruments. This allows data from all instruments to be connected and logged to a single, accessible location, which is the crest blockhouse at Anderson Dam. Access to surveillance data is automatic through polling software from a module in the blockhouse. The data are primarily accessed daily using satellite communication that sends all data to a District server. This server can be accessed by geologists and engineers through their computers of the Dam Safety Program, at District headquarters. This has the advantage that District personnel can remotely initiate unscheduled connections in the event of alarm conditions. Alternatively, recorded data may be accessed manually in the blockhouse at each instrument location. Another option is that District personnel can manually initiate access via the satellite connection from their computers.

4.2 Data Gaps

Gaps that occurred in the VWP data sets are discussed below in *Section 4.4.6 Piezometer Data Gaps*. Gaps that occurred in the in-place inclinometer sensor (IPIs) data sets are discussed below in *Section 4.7.3 IPIs Data Gaps*. No significant gaps occurred during the current reporting period in the monument survey data or new VWP data.

Gaps are defined differently for each particular instrumentation group based on the frequency that data are collected. For example, monument survey data are collected roughly annually (September or October each year). Consequently, a data gap for survey data is considered the absence of data over a period of plus or minus ~6 months outside the normally scheduled yearly survey.

One special category of data gaps are those related to ADAS. With the advent of ADAS and the frequent recording of data (1 time daily) from the VWPs and IPIs, we have developed a procedure to delineate significant data gaps, which for ADAS instruments is defined as the absence of recorded instrument data for a period greater than about 1 month. As discussed in our December 2009 surveillance report (Nelson, 2009), we set up the plotting software (Grapher software) to show data gaps.

Anderson Dam ADAS stations are currently working properly except for non-viable IPIs data and selected VWPs that require manual readings because of ongoing power supply issues. The District is making an assessment of this situation to determine if the problem is related to ADAS components or to problems with the instruments themselves. We will keep DSOD apprised on the results of this evaluation.

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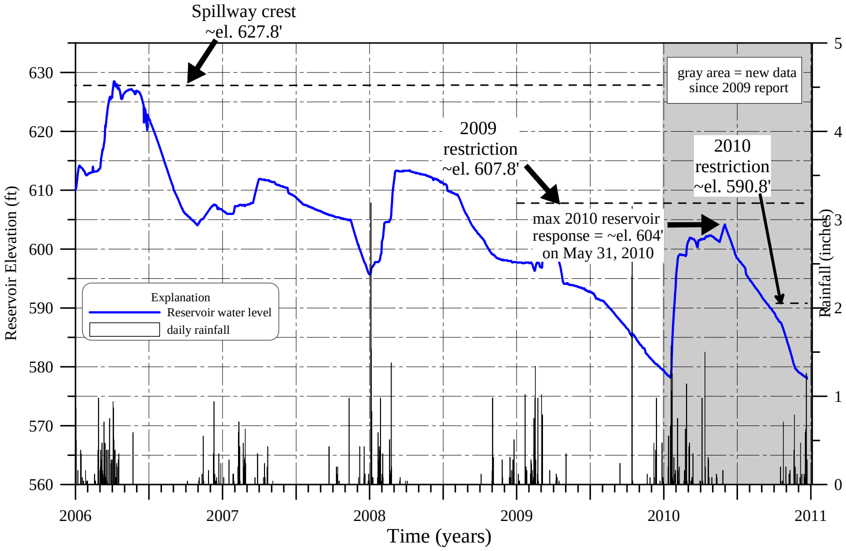
4.3 Annual Reservoir Fluctuation

This section briefly describes reservoir fluctuations during the current recording period and how they relate to restrictions. Also, some piezometric responses in the dam and foundation are potentially influenced by changes in reservoir levels as discussed in *Section 4.4.4 Piezometer Data.*

As summarized in a District document (WSOPAU, 2009), interim DSOD restrictions for Anderson were implemented and monitored by District Operations Planning and Analysis Unit (OPAU) beginning in January 2009. On December 29, 2008, the District submitted a copy of the AMEC Geomatrix Preliminary Seismic Stability Evaluation (AMEC, 2008) of Anderson Dam to both DSOD and FERC informing them of its findings. The District implemented an operating restriction that was ordered by DSOD in a letter dated January 26, 2009 to keep the reservoir below elevation 607.8 ft NAVD, which is ~20 feet below spillway ogee elevation, or a total restriction of ~40 feet below the dam crest. In September 2010, AMEC presented findings that confirmed Anderson Dam could be unstable in a major earthquake. As a result, the District proposed an addition restriction of ~17 feet for a total of 37 feet below the spillway and ~57 feet below the dam crest (District, 2010) which was accepted by DSOD in an October 14, 2010 letter. This new restriction is equivalent to elev. 590.8 feet (NAVD88). In Figures 5 through 9, the earlier restriction is labeled “2009 restriction” and the recent restriction is labeled “2010 restriction”.

Figure 5 shows the detail of reservoir fluctuation from 2006 through most of calendar year 2010 with gray shading that denotes recent data during the current surveillance period from January 2010 to the present. The maximum reservoir excursion for 2010 was el. 604.2 feet (~24 feet below spillway lip el.) on May 31, 2010. Recent prior maximum reservoir excursions in 2006, 2007, 2008, and 2009 were el. 628 feet, elev. 612 feet, elev. 613 feet, and elev. 602 feet respectively. The last time Anderson Reservoir spilled was in April 2006 (Nelson and Volpe, 2006). Since January 2009, Anderson Reservoir did not exceed the restriction elevation of 607.8 ft. Since September 2010, the reservoir level has been well below the newer 2010 restriction at elev. 590.8 ft. The preponderance of rainfall for any given calendar year typically occurs during January through April/May (locally known as a “water year”).



Notes: 1) basis of elevations is NAVD 1988 - values are 2.8 feet higher than NGVD 1929
2) file W:\geology\dams\annual dam safety reports\FERC\Annual Reports\2010\piez\Andresplot-10

Figure 5. Daily Reservoir Elevation and Rainfall 2006-2010

4.4 Piezometers

4.4.1 Pneumatic Piezometers

Two pneumatic piezometers (PPA-1 and PPA-2), installed in 1975, show slight fluctuations and response to changes in reservoir levels but are still operational after 34 years of service. From mid 2009 through early 2010, the pneumatic readout box failed and a replacement was obtained in early 2010. Consequently, there is a data gap in the pneumatic piezometers starting in July 2009 that continued through February 2010.

4.4.2 Vibrating Wire Piezometers

Table 1 summarizes pertinent data of the vibrating wire piezometers (VWP) including location in the dam, tip elevation and surface elevation. The District manually collected data from 31 VWPs from their installation in late December 2006 untel implementation of ADAS in early December 2008. Except for the VWPs mentioned below (yellow highlight), most data since December 2008 has been automatically collected by ADAS. The locations of the VWPs are shown in plan view in Figure 1 and in section views in Figures 2, 3, and 4.

Table 1
Locations of Vibrating Wire Piezometers
and Open Well Piezometers OW-2 and OW-3
Anderson Dam

Embankment Piezos		
Downstream Core Zone 3	Tip Elev. (ft)	Surface Elev. (ft)
72-9-02*	480	647
72-9-03*	531	647
72-9-04*	580	647
72-9-05	484	631
72-9-10*	430	647
72-9-11*	480	647
72-9-12*	530	647
72-9-13*	580	647
72-9-20	550	647
72-9-22*	450	647
72-9-23*	500	647
72-9-24*	550	647
72-9-26	550	647
72-9-29*	444	614
72-9-30*	490	614
Upstream Core Zone 2	Tip Elev. (ft)	Surface Elev. (ft)
72-9-14	470.0	630.0

Transition Zone		
Downstream	Tip Elev. (ft)	Surface Elev. (ft)
72-9-07	557	619
72-9-08	518	602
72-9-16*	539	614
72-9-17	421	583
Upstream	Tip Elev. (ft)	Surface Elev. (ft)
72-9-06	587.0	631
72-9-15	587.0	630.0
Foundation Fill Lower Finer Fill		
Foundation	Tip Elev. (ft)	Surface Elev. (ft)
OW-2	406	508

Bedrock Foundation		
Foundation	Tip Elev. (ft)	Surface Elev. (ft)
72-9-01	453	647
72-9-9B	382	647
72-9-18	580	647
72-9-19	516	647
72-9-21	400	647
72-9-25	500	647
72-9-27	585	647
Alluvial/Colluvial Foundation		
Foundation	Tip Elev. (ft)	Surface Elev. (ft)
72-9-28	405	486.0
72-9-31*	600	647
OW-3	408	551

Note:
1) * = piezometer installed using grout-in methods (see text)
2) all other piezometer installed using sand-pack methods (see text)
3) yellow highlight = piezometers that are being read manually due to power issues (see text)

As summarized in Table 1, locations of the piezometers include 16 VWPs in the downstream core (Zone 3) of the embankment, 1 VWP in the upstream core (Zone 2) (with core piezometers shown as red symbols in Figures 2, 3, and 4), 4 VWPs in the downstream transition zone (yellow symbols), 2 VWPs in the upstream transition zone, 2 VWPs in alluvium/colluvium (green symbols), and 7 VWPs in foundation Franciscan Complex bedrock (blue symbols).

Yellow highlight on Table 1 indicates 7 VWPs (1, 2, 3, 19, 22, 23, 24) that are currently being read manually because of ongoing power issues with ADAS. They include embankment piezometers 2, 3, 22, 23, 24 and foundation piezometers 1 and 19. Five of the VWPs (1, 2, 3, 19) with manual readings are in the left abutment and three VWPs (22, 23, and 24) with manual readings are in the right abutment. It should be mentioned that VWPs 5 and 20 are read by ADAS, but only intermittently. Twenty-four of the 31 VWPs, including all VWPs along the maximum section of the dam, are currently being read by ADAS.

4.4.3 Open Well Piezometers

Since September 2003, the District has collected water level data from open well piezometer OW-1 soon after the well was installed in August 2003. New open well piezometers OW-2 and OW-3 were installed on April 30, 2009 and May 1, 2009, respectively. The locations of the open well piezometers are shown in Figures 1 and 3. Piezometer OW-2 targets the phreatic surface of a lower fine-grained unit of rockfill embankment encountered during the SSE1A investigation and identified as the "Lower Finer Fill" (LFF) at depths between 89 feet and 105 feet (~elev. 403 feet and 419 feet). Well OW-3 targets the phreatic surface of various foundation soils including construction haul road fill and alluvium at depths between 132 feet and 141 feet (~elev. 410 feet and 418 feet).

AMEC collected a field water level reading on June 9, 2009 for SSE1A and the District began monitoring water levels on a regular basis (roughly monthly) in OW-2 and OW-3 in October 2009.

4.4.4 Piezometer Data

Recent pneumatic and newer open well piezometer data collected since our last report (Nelson, 2009) from December 2009 through December 2010 are summarized in Table 2.

TABLE 2
Recent Piezometric Data
Leroy Anderson Dam)

Date	Reservoir Level (ft)	PPA-1	PPA-2	OW-1	OW-2	OW-3	Monthly* Rainfall (in)
			Piezometric Surface Elevation (ft)				
12/22/09	579.9	NR	NR	405.9	405.9	411.5	2.9
2/2/10	595.7	NR	NR	406.9	407.5	411.7	7.1
2/25/10	598.8	574.4	494.9	406.5	404.9	412.6	3.2
3/15/10	601.7	569.9	495.0	406.6	406.9	411.8	1.5
4/15/10	602.1	571.4	496.7	406.4	406.8	411.7	3.5
5/18/10	601.3	572.0	491.2	406.3	406.7	411.7	0.4
6/15/10	601.5	572.0	494.5	406.3	406.7	411.7	0.0
7/14/10	597.4	572.0	495.5	406.1	406.8	412.0	0.0
8/16/10	593.5	571.9	495.5	406.0	406.7	411.6	0.0
9/15/10	590.6	571.2	493.2	405.9	406.7	411.6	0.0
10/20/10	587.3	569.7	492.0	405.9	406.8	411.6	1.2
11/17/10	581.1	569.1	505.3	405.9	406.7	411.6	1.9
12/20/10	578.4	570.9	498.2	405.8	406.6	411.5	2.4

Notes:
1) Piezometer data is Piezometric Surface Elevation (PSE in feet)
2) PSE = pressure head (ft) + elevation head (ft)
3) basis of elevations is NAVD 1988 - values in this table are 2.8 feet higher than NGVD 1929
4) NR = no readings collected
5) Installation dates: OW-1 on 8/5/03, OW-2 on April 30, 2009, and OW-3 on May 1, 2009

The piezometer data presented in Figures 6 through 8 are in the form of piezometric surface elevation (PSE) vs. time for each piezometer. The PSE is defined as the sum of the piezometer tip elevation (feet) and the hydraulic pressure head (feet).

Figure 6 shows pneumatic and open well piezometric levels as piezometric surface elevation (PSE), reservoir levels, and monthly rainfall data for the most recent 10 year period from January 2000 through December 2010. Table 2 and the gray area of Figure 6 show data since our 2009 report (Nelson, 2009).

Overall, the data indicates that fluctuations in these piezometric levels show a muted response to fluctuations in reservoir level. Pneumatic piezometers PPA-1 and PPA-2, located in the lower portion of the central clay core, consistently show minor variations in piezometric elevations under a wide range of reservoir fluctuations.

The pneumatic piezometer data appear to be providing reliable and consistent data during the entire surveillance period.

As shown in Figure 6, since installation, open well OW-1 (located about 50 feet from the downstream toe of the dam) has consistently ranged between ~elev. 403.7 feet and 406.6 feet, or ~10 feet to 13 feet below ground surface. For 2010, piezometric elevations in OW-1 were consistently ~elev. 406 feet to 407 feet, which corresponds to a depth of ~10 ½ feet below ground surface.

As shown on Figure 6, since installation of open wells OW-2 and OW-3, the PSE values of these wells has not varied much. OW-2 has varied from elev. ~405 feet to ~408 feet and OW-3 has varied from elev. ~411 feet to 413 feet. Long-term trends of the phreatic surface in these wells have not been established.

4.4.5 Vibrating Wire Piezometer (VWP)

The maximum Anderson Reservoir elevation since installation of the VWPs and their first readings in November 2006 was about 613.4 feet on April 9, 2008, which is about 14 feet below the spillway lip. The maximum for the current reporting period was 604.2 feet on May 31, 2010, which is about 24 feet below the spillway lip.

Figure 7 shows 3 plots of VWP surface elevation (PSE) data from the embankment versus time along sections A-A’, B-B’, and C-C’. Figure 8a shows plots of PSE data versus time for foundation bedrock and alluvium VWPs. Figure 8b show PSE data versus time for transition zone VWPs. Reservoir elevations and monthly rainfall data are presented for reference. Due to the 2009 reservoir restriction (~40 ft additional freeboard) since 2009, the VWPs installed in 2007 (DIP) and 2010 (SSE1B) have not experienced possible maximum VWP excursions. The recent data obtained since our last report (Nelson, 2010) from January 2010 through December 2010 is shown as a shaded region on Figures 7 and 8.

There are a number of pertinent observations based on VWP information to date. These are summarized below.

- Based on the muted response of core VWPs as indicated in Figures 7 and 8, hydraulic pressures being imposed by the dam are being safely dissipated by head losses through

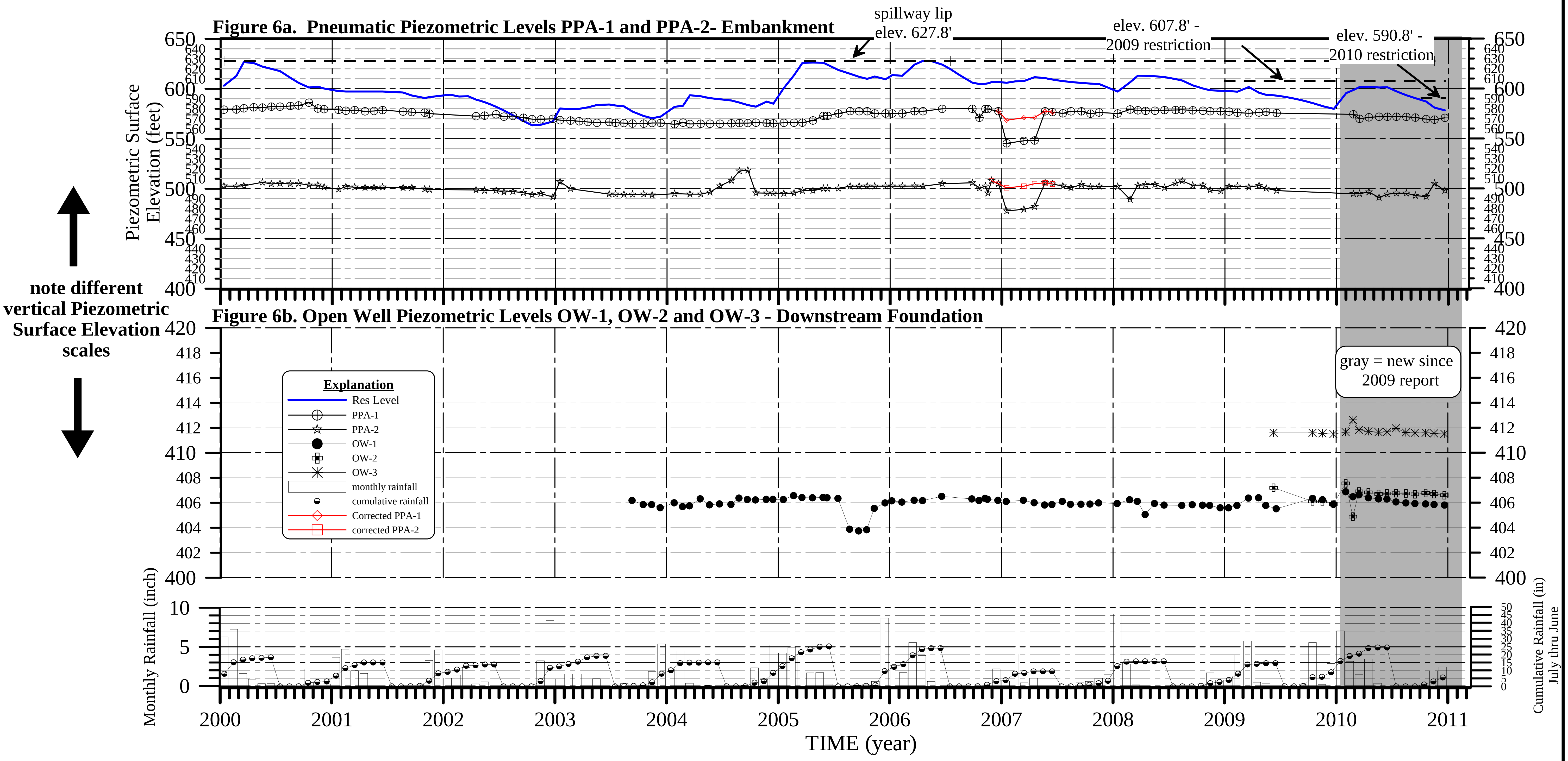


Figure 6a. Pneumatic Piezometric Levels PPA-1 and PPA-2- Embankment

Figure 6b. Open Well Piezometric Levels OW-1, OW-2 and OW-3 - Downstream Foundation

Notes:
1) Basis of elevations is NAVD 1988 - values on this plot are 2.8 feet higher than NGVD 1928
2) File W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\Anderson\2011\Piez\Andpneu&ows-10.grf

Santa Clara Valley Water District

Recent Piezometric Data - Pneumatic and Open Wells
Embankment & Downstream Foundation
Leroy Anderson Dam

FIGURE
6

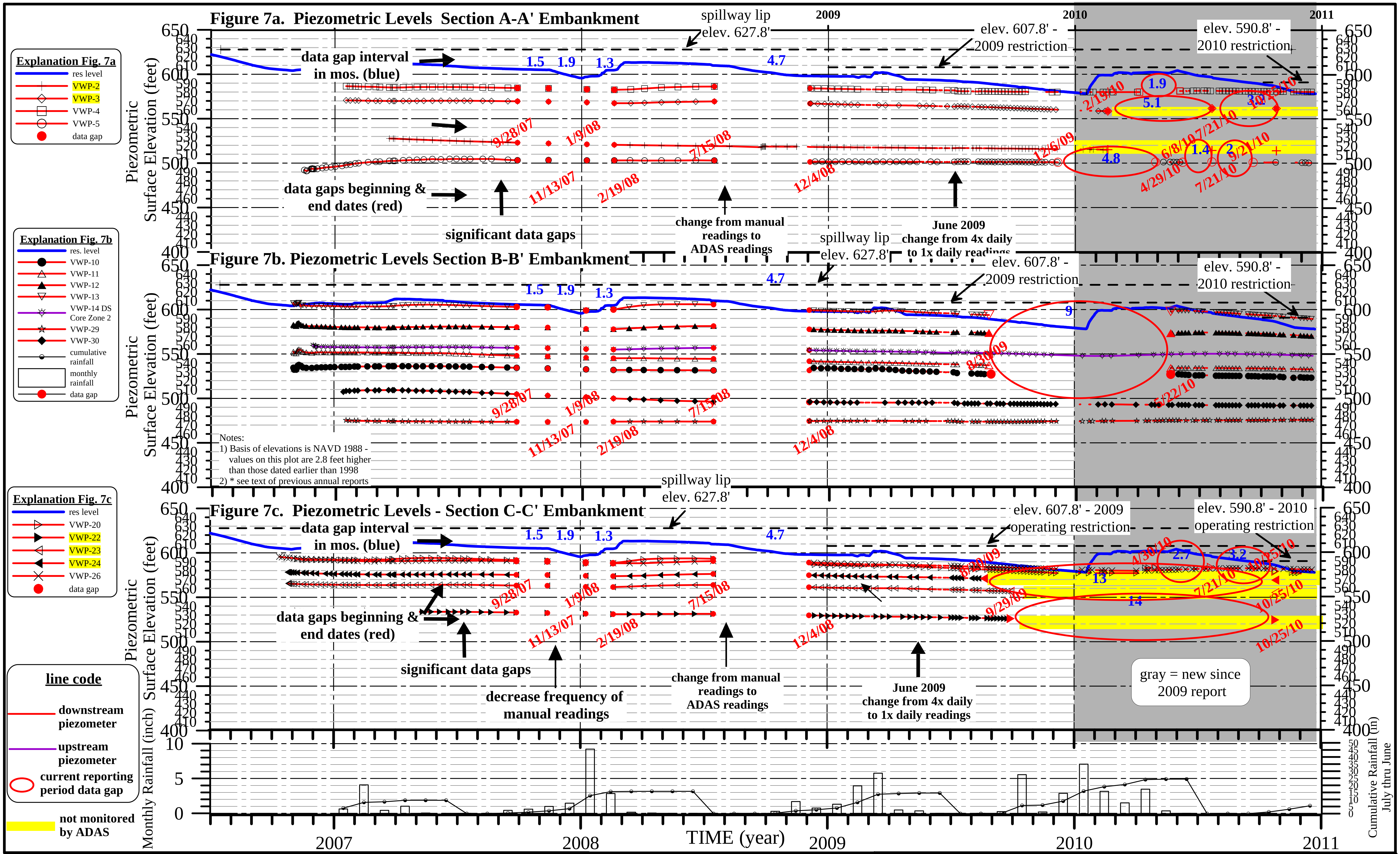


Figure 7a. Piezometric Levels Section A-A' Embankment

Figure 7b. Piezometric Levels Section B-B' Embankment

Figure 7c. Piezometric Levels - Section C-C' Embankment

Notes:
1) Basis of elevations is NAVD 1988 - values on this plot are 2.8 feet higher than NGVD 1928
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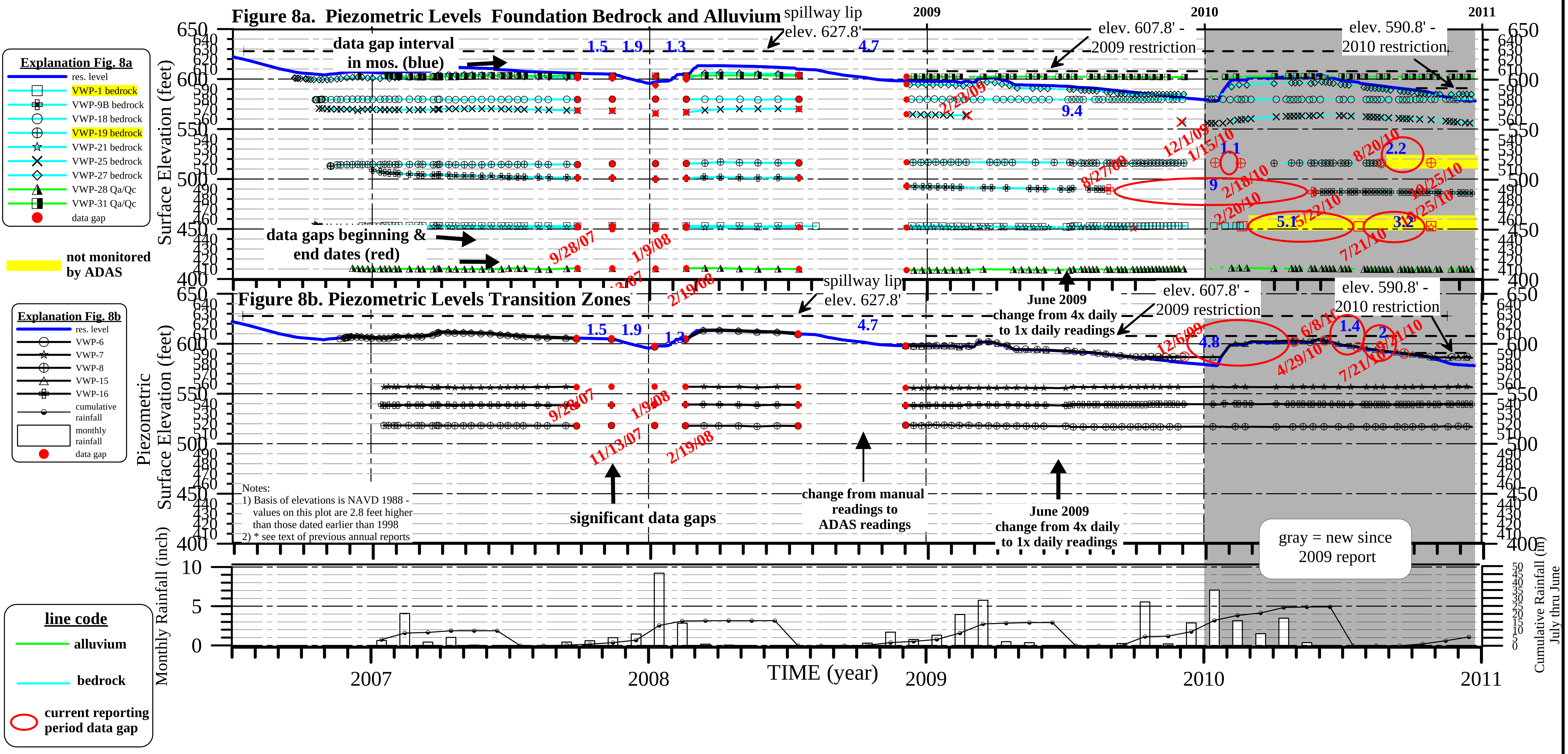
Santa Clara Valley Water District

Recent VW Piezometric Data
Sections A-A' through C-C' - Embankment
Leroy Anderson Dam

FIGURE
7



Notes:
1) Basis of elevations is NAVD 1988 - values on this plot are 2.8 feet higher than NGVD 1928
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Santa Clara Valley Water District

Recent VW Piezometric Data - Foundation and Transition Zones
Leroy Anderson Dam

FIGURE
8

the core in a safe and effective manner. This is evident by 16 VWPs located within the U/S Zone 2 and D/S Zone 3 core sections (see Table 1) that indicate no significant variations in hydraulic head losses across the entire width or length of the dam.

-
- Except for VWPs in the left abutment (18 & 31) and right abutment (25 & 27) (see discussion below), the majority of the foundation VWPs are measuring only a fraction of the total possible pressure head at various locations beneath the core of the dam (Figure 8a). This supports the effectiveness of the foundation preparation including the removal of surficial soils (i.e. alluvium and colluvium) beneath the core during construction and the fact that the vast majority of the clay core rests on and is in direct contact with either predominantly competent Franciscan Complex bedrock or semi-consolidated Santa Clara Formation sediments.

- The left and right abutment VWPs (18, 31, 25, and 27) in bedrock (Franciscan Complex and possibly Santa Clara Formation) appear to have relatively high PSE values based on their relatively high tip elevations (580 ft, 600 ft, 500 ft, and 585 ft, respectively) and the likelihood that these VWPs are located in bedrock that may be slightly more permeable than the clay core. VWP 18 is essentially dry with a PSE value close to the tip elevation; VWP 31 has PSE values ~2 ft higher than the tip elevation; VWP 25 has PSE values that range from ~55 ft to ~64 ft higher than tip elevation; and VWP 27 has PSE values that range from ~2 ft to 15 ft higher than the tip elevation. VWP 27 is also one of the few piezometers that noticeably respond to reservoir changes. VWP 31 is noteworthy because, regardless of how much the reservoir drops, the minimum PSE stays at about elev. 602 ft. Currently, PSE values in VWP 31 are at ~elev. 602.1 ft while reservoir elevation is ~elev. 578 ft, indicating that the phreatic level in VWP 31 is ~24 ft higher than the reservoir. The tip of VWP 31 is located at a relatively high elevation (~600 ft) in the left abutment. This higher pore pressure response relative to reservoir levels likely reflects the concept of storage retention or field capacity when a porous media is drained. It is also possible that local groundwater conditions govern the water level in VWP 31.

- Based on the results of two upstream transition zone VWPs (6 and 15), there is essentially no loss (dissipation) of reservoir head through the upstream rockfill shell and transition zone, which means that the full reservoir hydrostatic head is acting along the upstream sloping face of the core. This performance is expected because the upstream rockshell and transition zones are very permeable.

- Four VWPs were installed within the downstream transition zone, including 7 and 8 in Section A-A (Figure 2), and 16 and 17 in Section B-B’ (Figure 3). These four VWPs are all measuring PSE values essentially at their respective tip elevations indicating that the phreatic surface in these VWPs is below the tip (i.e. dry holes), which indicates that the downstream transition zone and overlying rockfill zone are essentially dry. These results indicate that the transition zone is effectively capturing the phreatic surface as it exits the downstream face of the core.

- VWP 72-9-28, OW-1, OW-2, and OW-3 are located in the downstream foundation, with OW-1 actually located about 50 feet beyond the downstream toe very close to the maximum section. OW-2 and OW-3 monitor the downstream foundation consisting of lower finer fill (OW-2) and alluvium (OW-3). These VWPs have a drop in maximum PSE value of about 4.7 feet over a horizontal distance of about 400 feet. This computes to a relatively low horizontal seepage gradient of about 0.02 (6’/400’) in the downstream toe area.

Except for the 4 VWPs in the upsteam transition zone that directly respond to fluctuations in reservoir levels, the older open well, pneumatic wells, and VWPs indicate that piezometric levels generally exhibit a muted response, meaning that they don’t seem to track the reservoir excursions. This is due to the low permeability clay core. The piezometric levels in all piezometers tend to fall within the typical ranges of historical levels. No abnormal readings or trends are evident.

As evident from Figures 6b, A-35, and A-36, not enough data has been collected from open wells OW-2 and OW-3 to evaluate their long-term response to changes in reservoir levels. Based on limited data, these piezometers appear to respond similar to OW-1

4.4.6 Piezometer Data Gaps

There is a data gap in the pneumatic piezometers starting in July 2009 that continued through February 2010 that was related to obtaining a new readout box.

Due to ongoing power supply issues, there are significant data gaps with durations of 2 months to 14 months for 7 VWPs (1, 2, 3, 19, 22, 23, and 24). These piezometers are highlighted in yellow on Table 1 and Figures 7a, 7c, and 8a. Specifically, several battery/solar panels at the dam site are constantly drained of power and are not recharged by the solar panels. There may be flaw in the original construction that causes these systems to be constantly drained of power. The District is currently working to resolve the power issues in 2011, with the goal to obtain continuous data readings from the 7 VWPs. The District will keep DSOD apprised of this work.

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4.5 Spillway Underdrain System

The current spillway underdrain seepage monitoring program for Anderson Dam Spillway began in May 1993. At that time, the District only measured the "center" drainage system which collects seepage in the central portion of the spillway. The "left" drainage system discharged through boulders that were providing slope protection D/S of the spillway bucket and could not be measured.

The seepage system was modified with the construction of the two "V" notch seepage weirs in 1999 (with readings beginning April 2000) to allow measuring all of the seepage instead of only a portion of the flow as occurred with the original center drainage system mentioned above. Weir #1 continues to measure the seepage from the "center" drainage system but is not affected by the restriction and backpressure created by the use of a meter, as was the old system that it replaced. Weir #2 measures the seepage collected along the left (southern) side of the spillway.

4.5.1 Spillway Underdrain Flow Data

Our surveillance reports only provide historic data plots covering the last 10 years (since ~ 2000). Spillway underdrain flow data was formerly collected using a flow meter. This report only shows plots of the weir discharge data. Historic flowmeter data are summarized in previous surveillance reports. Figure 9 show monthly rainfall and data from weirs No. 1 and No. 2 from April 2000 through December 2010. Table 3 shows recent data since the 2009 report.

During 2010, the combined flow from the weirs ranged from a low of ~10 gallons per minute (gpm) (February 2010) to a high of ~64 gpm (May 2010). The overall flow is relatively small during the period of this surveillance report due to relatively low reservoir levels as discussed in *Section 4.3 Annual Reservoir Fluctuation*.

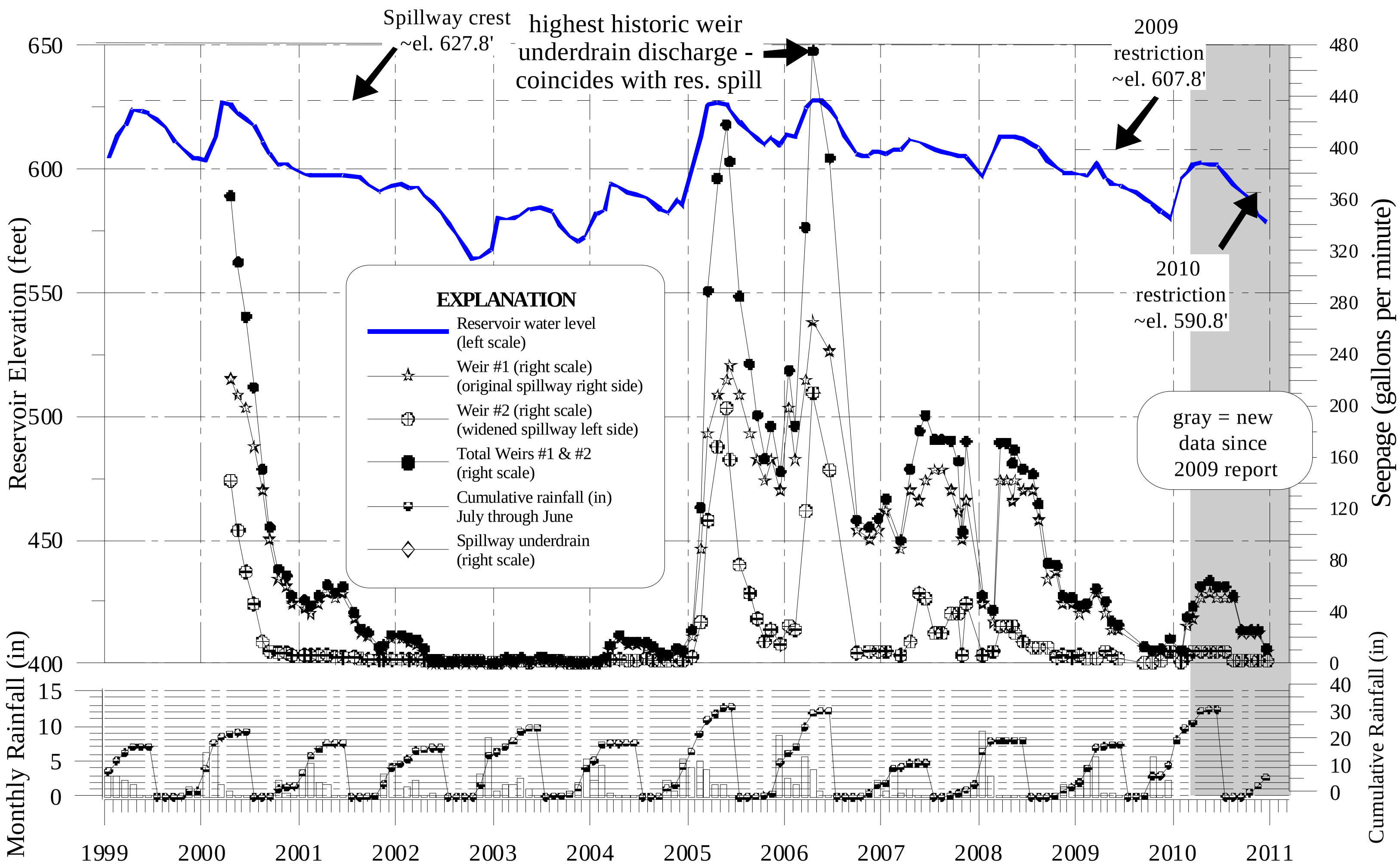
TABLE 3
Recent Weir Discharge Data – Spillway Underdrains
Leroy Anderson Dam

Date	Reservoir	Underdrain	flow (gpm)	Total flow
	Level (ft)	Weir No. 1	Weir No. 2	(gpm)
12/22/2009	579.9	9.4	9.4	18.9
2/2/2010	595.7	9.4	0.9	10.3
2/25/2010	598.8	29.2	6.3	35.5
3/15/2010	601.7	34.6	9.4	44.0
4/15/2010	602.1	50.3	9.4	59.7
5/18/2010	601.3	54.3	9.4	63.7
6/15/2010	601.5	50.3	9.4	59.7
7/14/2010	597.4	50.3	9.4	59.7
8/16/2010	593.5	50.3	2.3	52.6
9/15/2010	590.6	23.3	2.3	25.6
10/20/2010	587.3	23.3	2.3	25.6
11/17/2010	581.1	23.3	2.3	25.6
12/20/2010	578.4	9.4	1.8	11.2

Notes: 1) Weir No. 1 collects flow from the central portion of spillway
2) Weir No. 2 collects flow from the left side of the spillway

4.5.2 Spillway Underdrain Flow Data Gaps

There were no significant underdrain flow data gaps during the current reporting period.



Notes: 1) Basis of elevations is NAVD 1988 - values on this plot are 2.8 feet higher than those dated earlier than 1998
2) File: W:\geology\dams\annual dam safety report\FERC\annual reports\2010\piez\andweir-10.grf

Figure 9. Weir Discharge Data - Spillway Underdrains

4.6 Monument Surveys

4.6.1 Survey Procedures

Crest monuments were surveyed at the times indicated (typically once per year). Vertical survey data is collected and processed following the same methods used previously, traditional closed loop least squares adjusted leveling technique. Survey of monuments at Anderson Dam consists of using GPS techniques with data format in X-Y coordinates (eastings and northings, respectively). Previous survey techniques of the original crest monuments consisted of offset (transverse) displacements either upstream or downstream relative to the monument line established soon after the dam was constructed. These data are calculated from the coordinate data using trigonometric relationships assuming stable reference points away from the dam and located in the right and left abutments. The reference baseline for the transverse displacement calculation uses the coordinates of the end points, assumed to be relatively stable monuments in bedrock immediately right and left of the dam, at the time the survey was first established. It should be noted that the GPS survey (northing, easting, and vector displacements) do not utilize local stable endpoints, but a regional GPS station, and thus produce somewhat different results with respect to points of reference.

During the period of this report, crest monuments (No. 16 through No. 30) and training wall monuments (No. 14 and No. 15) were monitored at the locations shown in Figure 1 (plan view) and in Figure 4 (longitudinal section view).

Since July 1988 the District has used Global Positioning Satellite (GPS) methods to survey new crest monuments installed at Anderson Dam after the 1986-87 dam raise.

Before 1988, and the introduction of GPS surveys with the resulting data provided in the form of coordinates (Northings and Eastings), previous transverse data consisted of offset displacements either upstream or downstream relative to the monument line established soon after the dam was constructed.

“Vertical” and “transverse” survey data collected since the December 2009 report (Nelson, 2009) are shown as gray shading on Figures 10 and 11.

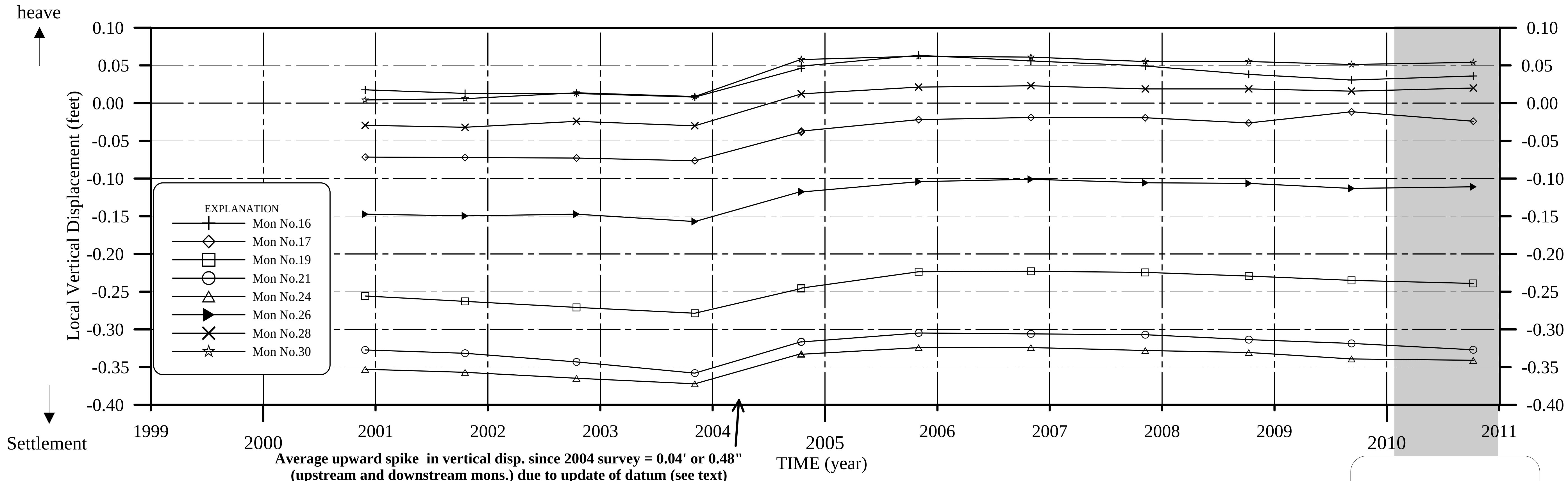
4.6.2 Dam Crest and Abutment Monuments

The crest monuments generally alternate between the downstream edge and upstream edge of the crest. Data plots have been grouped as either “upstream (U/S) edge” or “downstream (D/S) edge”. The location of the surface monuments are shown in Figure 1 (plan view) and Figure 4 (longitudinal section view).

As noted in previous annual surveillance reports, because monument 31 was destroyed during the 2003/2004 boat ramp construction, the new left abutment control endpoint is monument 30, which is used as a reference point to determine local transverse displacements.

4.6.3 Survey Data – Dam Crest and Abutments

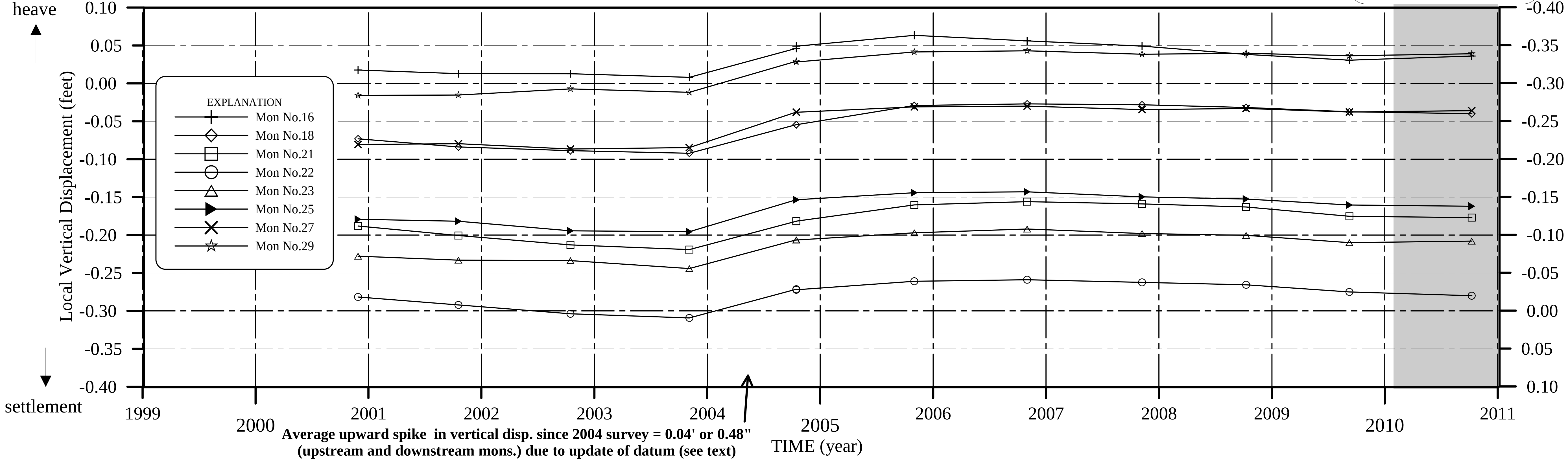
During the period of this report, dam crest monuments No.16 through No. 30 were monitored and their locations are shown on Figure 1. The vertical and transverse data for Anderson Dam is presented in Figures 10 and 11, and summarized on Table 4. Net vertical and transverse



Average upward spike in vertical disp. since 2004 survey = 0.04' or 0.48"
(upstream and downstream mons.) due to update of datum (see text)

Figure 8a. Recent Local Vertical Displacements - Downstream Monuments

gray = new data since
Dec 2009 report



Average upward spike in vertical disp. since 2004 survey = 0.04' or 0.48"
(upstream and downstream mons.) due to update of datum (see text)

Figure 8b. Recent Local Vertical Displacements - Upstream Monuments

Notes:
1) File W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\Anderson\2011\survey\AndDS&USvertPlots-10.grf
2) Since the 2004 survey the District no longer shows changes in datums

Santa Clara Valley Water District

Recent Local Vertical Displacement
- Downstream and Upstream Crest Monuments
Leroy Anderson Dam

FIGURE
10

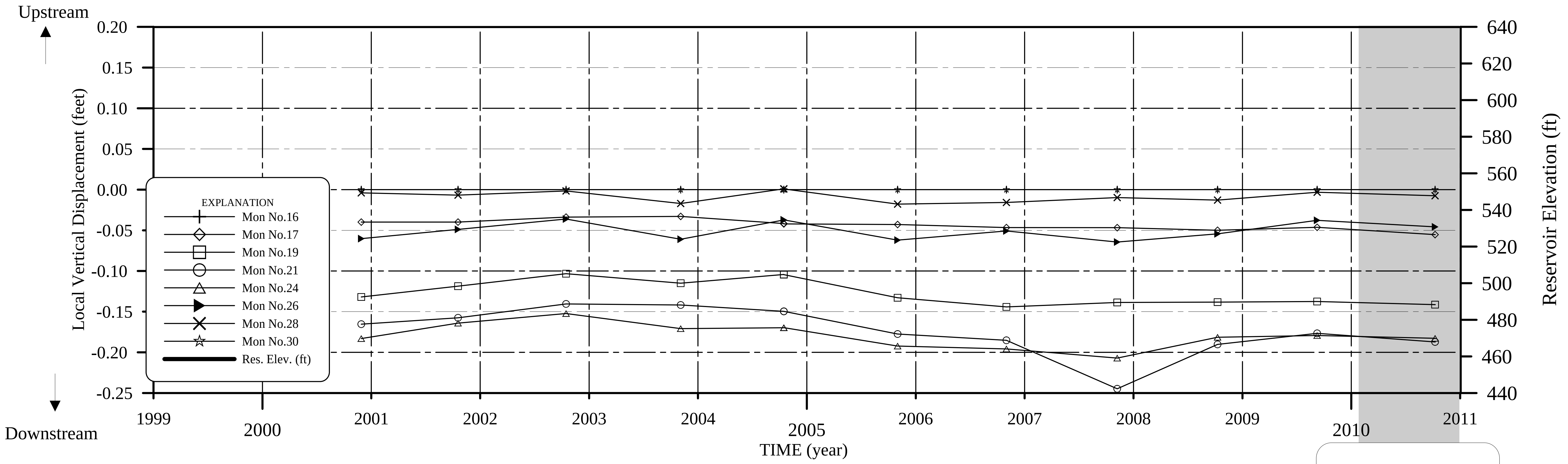


Figure 9a. Recent Local Transverse Displacements - Downstream Monuments

gray = new data since Dec 2009 report

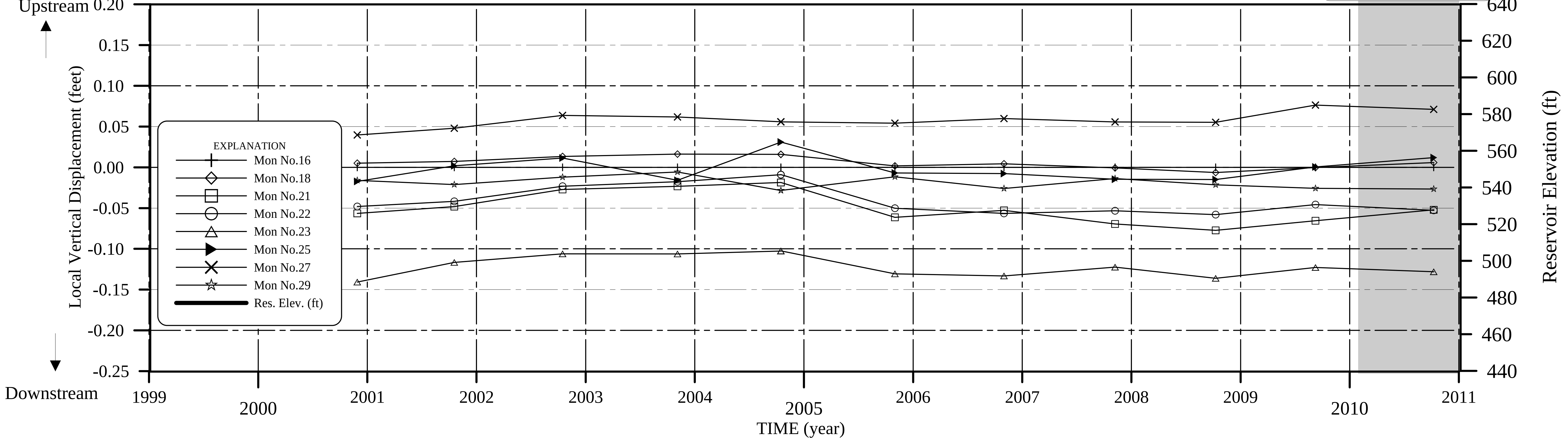


Figure 9b. Recent Local Transverse Displacements - Upstream Monuments

Notes:
1) File W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\Anderson\2011\survey\AndDS&UTransPlots-10.grf
2) Since the 2004 survey the District no longer shows changes in datums

Santa Clara Valley Water District

Recent Local Transverse Displacement
- Downstream and Upstream Crest Monuments
Leroy Anderson Dam

FIGURE
11

displacements since the last surveillance report (i.e. from September 2009 to the October 2010) is shown at the bottom of each data set on Table 4.

Survey results of crest and abutment monuments indicate minimal horizontal and vertical displacements (less than 0.01 ft in the vertical plane and 0.01 in the horizontal plane) have occurred during this reporting period. These small displacements indicate that only minimal, normal displacements of the dam have occurred during this reporting period with no obvious trends.

TABLE 4
Vertical and Local Transverse Data - Crest and Abutment Monuments
Leroy Anderson Dam

Date	Cumulative Monument Vertical Displacement (feet) (since 1988)														
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
9/8/2009	0.03	-0.01	-0.04	-0.23	-0.18	-0.32	-0.28	-0.21	-0.34	-0.16	-0.11	-0.04	0.02	0.04	0.05
10/8/2010	0.04	-0.02	-0.04	-0.24	-0.18	-0.33	-0.28	-0.21	-0.34	-0.16	-0.11	-0.04	0.02	0.04	0.05
change in disp.	0.01	-0.01	0.00	0.00	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9/09 to 10/10		Average change since last survey =					0.00	or 0.0"							

Date	Cumulative Dam Crest Monument Local Transverse Displacement (feet) (since 1988)														
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
9/8/2009	0.00	-0.05	0.00	-0.14	-0.07	-0.18	-0.05	-0.12	-0.18	0.00	-0.04	0.08	0.00	-0.03	0.00
10/8/2010	0.00	-0.06	0.01	-0.14	-0.05	-0.19	-0.05	-0.13	-0.18	0.01	-0.05	0.07	-0.01	-0.03	0.00
change in disp.	0.00	-0.01	0.01	0.00	0.01	-0.01	-0.01	-0.01	0.00	0.01	-0.01	-0.01	0.00	0.00	0.00
9/09 to 10/10		Average change since last survey =					0.00	or 0.12"							

Notes:
1) Negative transverse displacement signifies downstream movement
2) Positive transverse displacement signifies upstream movement
3) Displacement is net displacement since 1988
4) NR = monument not surveyed (Mon. 31 destroyed during new boat ramp construction; Mon. 30 new control pt)
5) Local Transverse data shown back calculated to 1988 - see text
6) Mons #16 and 30 are control points and do not show local transverse displacement

4.6.4 Monument Survey Data Gaps

There were no significant survey data gaps during the current reporting period.

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4.6.5 Spillway Training Wall Monuments

Three survey monuments are located at the top of the spillway training walls, two on a wall on the left side of the spillway ogee (mons. 14 and 15), and one on a wall on the right side of the ogee (mon. 13), as shown in Figure 1. It should be noted that monument 13, on the right spillway wall, has not been monitored since October 2001. Also, previous spillway training wall horizontal and vertical survey results may be questionable due to access issues. Because of the difficulty of accessing the monuments positioned at the bottom of a chain link fence, some errors may be introduced in the survey data from the spillway training walls (see Nelson and Volpe, 2004 for more information). Even with these limitations this surveillance report provides historic data plots showing vertical displacement of Monuments 14 and 15 in Figure 12.

4.6.6 Survey Data – Training Wall

During the period of this report, Dam crest monuments No.14 and No. 15 are monitored and their locations are shown on Figure 1. The vertical data for the training walls presented in Figure 12, and summarized on Table 5. Net vertical and transverse displacements since the last surveillance report (i.e. from September 2009 to the October 2010) is shown at the bottom of each data set on Table 5.

Survey results of crest and abutment monuments indicate minimal horizontal and vertical displacements (less than 0.01 ft in the vertical plane) have occurred during this reporting period. These small displacements indicate that only minimal, normal displacements of the dam have occurred during this reporting period with no obvious trends.

TABLE 5
Vertical Displacement Data
Spillway Training Wall Monuments
Leroy Anderson Dam

Date		Monument Vertical Displacement (feet)		
		13	14	15
9/8/2009		NR	0.04	0.06
10/8/2010		NR	0.03	0.06
change in disp. 09/09 to 10/10		NR	-0.01	0.00

change since 9/09 = -0.01 or 0.12"

Notes:
1) Negative vertical displacement represents settlement
2) Positive vertical displacement represents heave

4.6.7 Spillway Training Wall Survey Data Gaps

There were no significant training wall survey data gaps during the current reporting period.

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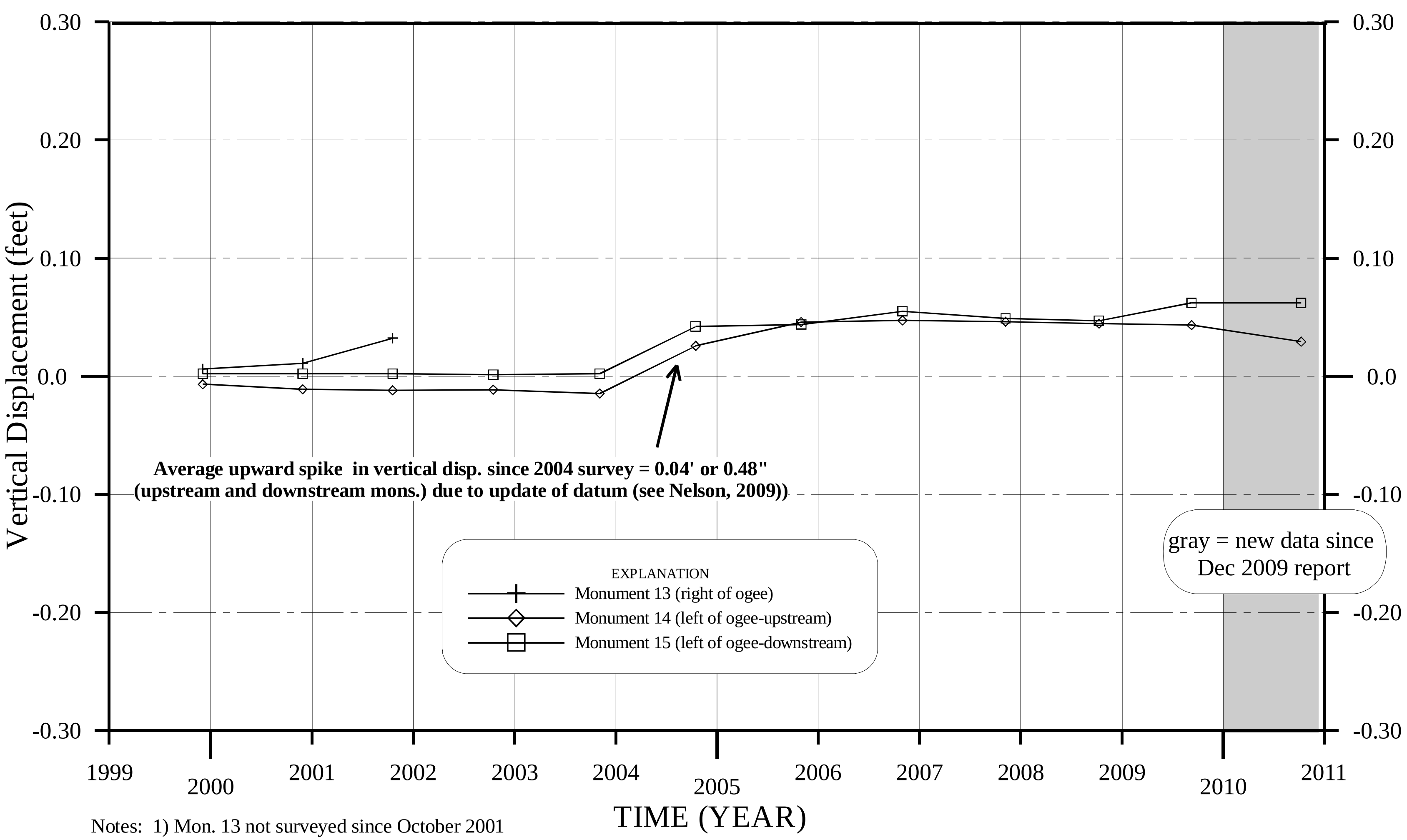

Notes: 1) Mon. 13 not surveyed since October 2001
2) File W:\geology\annual dam safety reports\DSOD\Anderson\annual reports\2010\survey\AndtrainWVert-10.grf
3) Since the 2004 survey the District no longer shows changes in datums

Figure 12 - Vertical Displacements - Spillway Training Walls

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4.7 In-Place Inclinometer Sensors (IPIs)

Six Little Dipper bi-axial sensors known as in-place inclinometer (IPIs) are located in inclinometer boring IPI9-1 (boring 72-9-ASI-1) shown on Table 6 and in Figure 1 (plan view) and Figures 3 and 4 (section view). The purpose of the IPIs is to monitor gross internal movements of Leroy Anderson Dam such as those that could occur during a significant earthquake or rapid drawdown of the reservoir. In District surveillance reports, we use the following abbreviations to differentiate between the individual in-place inclinometer boring (IPI) and in-place inclinometer Little Dipper bi-axial sensors (IPIs).

For clarity we decided to renumber the original DIP designation IPI9-3 for inclinometer boring to the current designation of IPI9-1 and sensors to the current designations of IPIs9-1 through 9-6.

4.7.1 IPIs Data

Table 6 summarizes pertinent information on each IPIs including IPIs designation, drill hole designation, sensor depth, sensor elevation, and surface elevation at the top of the inclinometer boring.

Table 6
Locations of In-place Inclinometer Sensors (IPIs)
Leroy Anderson Dam

Crest Inclinometer IPI9-1* (boring 72-9-AS1)				
IPIs Designation	**X-axis & Y-axis**	Spacing between sensors (ft)	Sensor Depth (ft)	Sensor Elev. (ft)
IPIs9-1	9-1X	36.5	36.5	610.5
	9-1Y	"	"	"
IPIs9-2	9-2X	21.5	58	589.0
	9-2Y	"	"	"
IPIs9-3	9-3X	21.5	79.5	567.5
	9-3Y	"	"	"
IPsI9-4	9-4X	21.5	101	546.0
	9-4Y	"	"	"
IPIs9-5	9-5X	21.5	122.5	524.5
	9-5Y	"	"	"
IPIs9-6	9-6X	51.5	174	473.0
	9-6Y	"	"	"

notes:
1) * = formerly designated as IPI9-3
2) sensor spacing includes length of fiberglass connector rod and length of senso
3) +Y axis is pointing upstream and +X axis is pointing to the left abutment
4) Boring surface elevation = 647 ft (at crest)
5) yellow shading = IPIs9-6 not functioning since 7/09

Our evaluation of IPIs data from Districts dams with DIP instrumentation (Anderson, Almaden, Calero Main, and Guadalupe Dams) indicates that ADAS for all these dams hasn't collected viable IPIs data since startup of the system in December 2008. Consequently, the District has been periodically collecting manual field reading. We are providing IPIs data from the manual field readings in our surveillance reports and are currently looking at possible remedies for correcting the problems with the IPIs including installing upgraded field modules from the manufacturer. We will continue to monitor field manual voltmeter IPIs data for any trends and we will keep DSOD apprised.

We will continue to analyze the IPIs data using a voltmeter to collect manual field readings, but will discontinue analyzing IPIs data from ADAS until the problems are rectified. As more IPIs data is gathered using a voltmeter, we will continue to evaluate the utility of the IPIs sensors to determine if they can provide sufficient reliability and accuracy to warrant continued use.

4.7.2 In-Place Inclinometer Sensor Data

In an effort to aid review of surveillance data by condensing plots, Figure 13 is a compilation of X-axis and Y-axis data plots for all IPIs. Also, to comply with FERC's request (FERC, 2010b), the District now includes plots of inclinometer readings versus depth (i.e. elevation of sensor) as shown in Figure 13. Plots of incremental X-axis and cumulative X-axis data are shown in Figures 13a and 13b, respectively. Plots of incremental Y-axis and cumulative Y-axis data are shown in Figures 13c and 13d, respectively.

Two apparent minor deflections are evident on Figures 13a through 13d. An apparent deflection of ~0.4 inches is evident in IPIs 9-4 in the right abutment (negative X) direction and the downstream (negative Y) direction. An apparent deflection of ~0.4 inches is evident in IPIs9-2 in the right abutment (negative X) direction. It appears likely that these deflections indicate either 1) minor adjustments of the IPIs in the casing, 2) minor adjustments of the casing itself with time, or 3) normal variation in readings. The absence of progressively increasing deflections in IPIs9-1 through IPIs9-6 with time indicates that no obvious movements are occurring at depth in the vicinity of the crest. We will keep DSOD apprised of any adverse trends in the IPIs data.

It is customary to assume that the bottoms of inclinometer borings are stable in order to calculate relative displacements upward along the entire length of the boring column. This is reasonable because the bottom of the inclinometer casing IPI9-1 is socketed into stable bedrock.

It should be noted that bottom IPIs9-6 at elevation ~473 feet hasn't provided reliable readings since July 2009 (yellow shading in Table 6). The readings are obviously spurious because the manual readings do not stabilize (i.e. volt readings constantly drift). Although not considered reliable, we assumed that IPI9-6 was relatively stable (zero displacement) for calculating relative displacements. The intended design of the IPIs for the dam instrumentation program (DIP) at Anderson Dam was to place the bottom sensor at such a depth that it is relatively low within the embankment (i.e. surrounded by laterally continuous earth materials) and thus could essentially be considered stable. At elevation 473 the total lateral extent of the embankment (core plus shell) in the upstream/downstream direction is ~900 feet, with ~450 feet upstream and ~450 feet downstream. The District will replace IPIs9-6 if it continues to provide unreliable readings and will keep DSOD apprised of this situation.

4.7.3 IPIs Data Gaps

Our interim manual reading IPIs program involves collecting data roughly on a quarterly basis (4 times a year), until the ADAS issue is resolved. No significant gaps in the IPIs data are present.

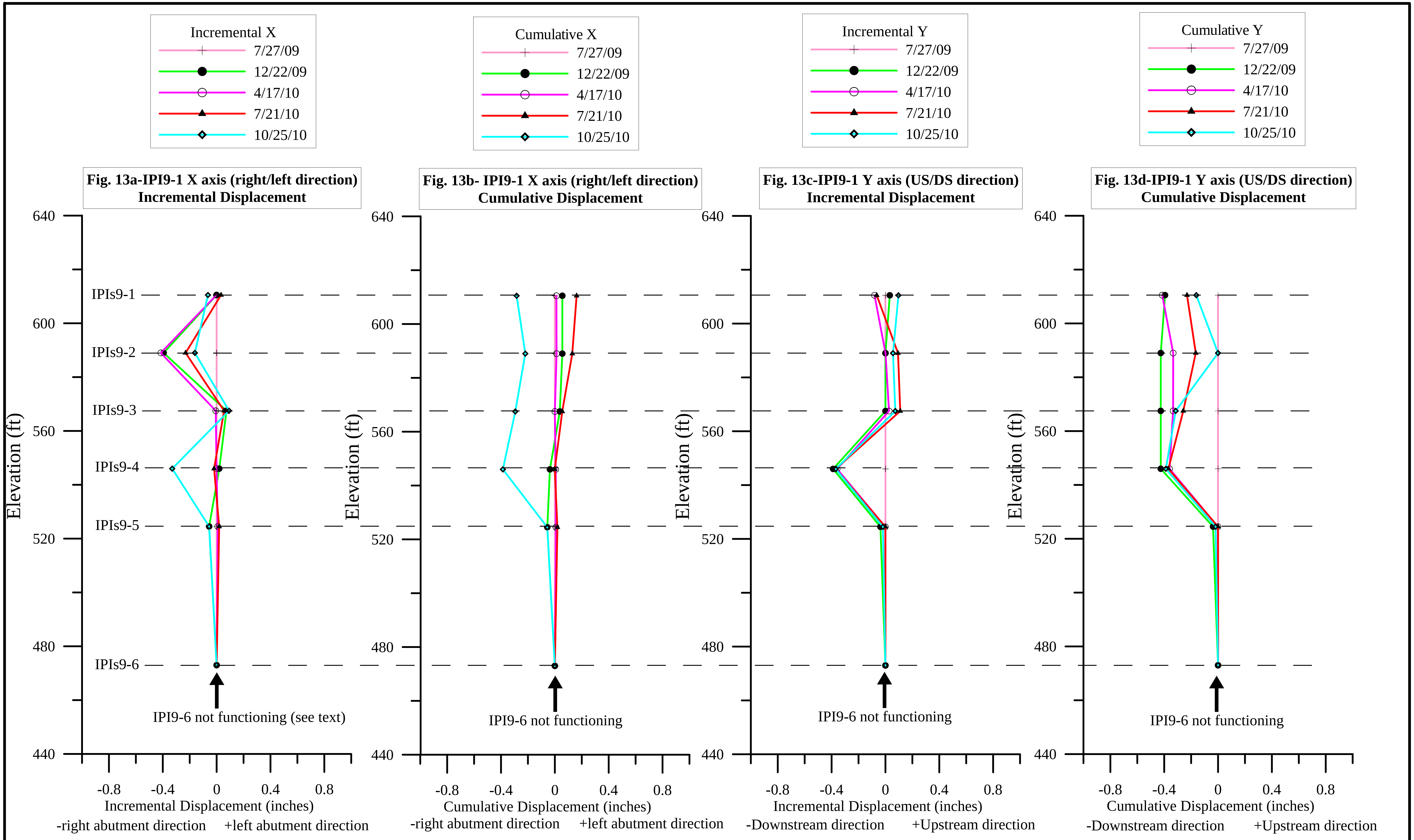

Fig. 13a-IPI9-1 X axis (right/left direction)
Incremental Displacement

Fig. 13b- IPI9-1 X axis (right/left direction)
Cumulative Displacement

Fig. 13c-IPI9-1 Y axis (US/DS direction)
Incremental Displacement

Fig. 13d-IPI9-1 Y axis (US/DS direction)
Cumulative Displacement

Notes:
1) Basis of elevations is NAVD 1988 - values on this plot are 2.89 feet higher than NGVD 1928
2) File W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\Anderson\2011\IPIs\AndIPIsX&Y.grf

Santa Clara Valley Water District

Recent In-Place Crest Inclinometer Sensor Data

Leroy Anderson Dam

FIGURE
13

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4.8 U.S.G.S. and District Strong Motion Accelerometers

4.8.1 U. S. Geological Survey Accelerometers

Seven Kinematrics Model SMA-1 strong motion recorders (accelerometers) were installed in 1985 by the U.S. Geological Survey (U.S.G.S). Five accelerometers are installed on the downstream slope, one is situated about 150 feet south-southwest of the crest in the left abutment (see Figure 1), and one free field accelerometer is situated about 300 feet downstream of the toe of Anderson Dam. The accelerometers are operated and maintained by the U.S.G.S. District Dam Safety Program Unit personnel request seismic data from the U.S.G.S. if the seven instruments have recorded seismic accelerations after significant earthquakes occur in the vicinity of Anderson Dam.

There are no accelerometer data to report since the October 31, 2007 Alum Rock earthquake event (2007 Annual report, Nelson and Volpe, 2008).

4.8.2 District Accelerometer

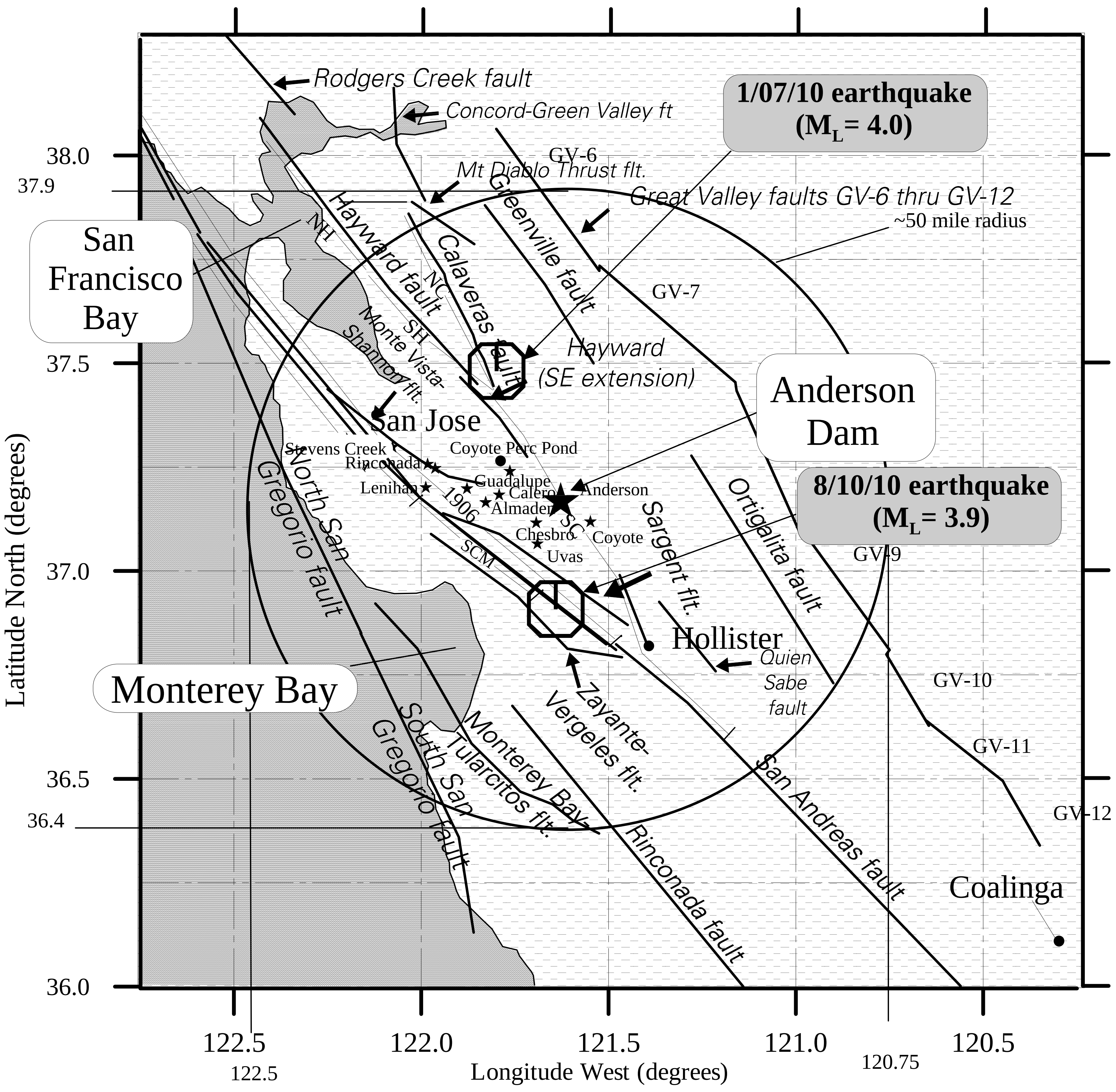
An Altus Etna strong motion accelerometer manufactured by Kinemetrics is securely mounted on the floor of the blockhouse on the crest of the dam. The purpose of the accelerometer is to record accelerations in the vicinity of the dam in the event of an earthquake. The accelerometer continuously monitors ground acceleration and compares current acceleration levels to preset thresholds. When an excursion of the threshold acceleration value is detected, ADAS notifies the District with an alarm that the threshold condition (typically 0.03 g) was exceeded. No alarms were triggered during the period of this report.

ADAS is set up to query the accelerometer for possible data at a 10-minute frequency during every 24 hour period. In addition, ADAS routinely retrieves data from VWPs and IPIs every 10 minutes. These frequent-interval data are temporarily stored in flash cards in the ADAS instrumentation center located onsite in the block house on the crest of Anderson Dam. These data are only retrieved manually by District Dam Safety Program personnel after they have been alerted to an alarm condition of the accelerometer. Data flash cards are retrieved from the dam and taken back to the office, where all pertinent ADAS data recorded at 10-minute intervals are then compiled and analyzed.

5.0 SIGNIFICANT AND NOTEWORTHY SEISMICITY

There were no earthquakes greater than M_L 5.0 during the reporting period from December 2009 through December 2010. Significant earthquakes are defined as having approximate magnitudes greater than M_L 5.0. Noteworthy earthquakes, defined as having approximate magnitudes less than M_L 5.0 but greater than about 4.0 occurred at two locations in the San Francisco Bay Area, during the reporting period from December 2009 through December 2010 (Figure 14) with the following date, magnitude, distance and direction from Anderson Dam.

1. On January 7, 2010, a magnitude 4.0 earthquake occurred about 24 miles northwest of the dam
2. On August 10, 2010, a magnitude 3.9 earthquake occurred about 18 miles south of the dam



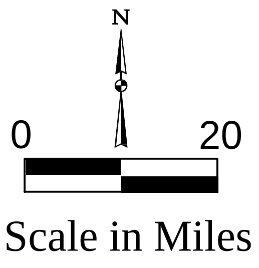
Explanation

⬣ Noteworthy earthquakes (see text)

★ District Dams

Fault segment abbrivations/ Probability of Magnitude 6.7 or greater occuring in next 30 years

NC = Northern Calaveras
CC = Central Calaveras
SC = Southern Calaveras/ 18%
PSSA = Peninsula Segment of the San Andreas/ 21%
SCM = Santa Cruz Mts.
1906 = 1906 EQ
NH = Northern Hayward/ 32%
SC = Southern Hayward
GV = Great Valley
Concord-Green Valley/ 6%
San Gregorio/ 10%
Mt. Diablo thrust fault/ 4%
Greenville/ 6%



Site Coordinates: Latitude: 37.165 N
Longitude: 121.629 W

Notes: 1) File W:\geology\dams\annual dam safety reports\DSOD\Anderson\2011\seis\Andseis-10.grf

DATE 12/1/09
DESIGN JLN
DRAWN JLN
CHECKED FBB

Santa Clara Valley Water District

Regional Fault Map Showing Noteworthy Earthquakes

Leroy Anderson Dam

SCALE 1"=20'

FIGURE 14

6.0 VISUAL INSPECTIONS AND MAINTENANCE ISSUES

The following significant inspections were performed during the period of this report include:

1. No DSOD inspection of Anderson Dam was performed during the current reporting period. The last DSOD inspection was on October 6, 2009.
2. On June 22, 2010 District staff (D. Hook, B. Baker, S. Wu, R. Jacobs, J. Sparkman, M. Hammer, M. Gamez, and J. Nelson) and FERC Engineers E. Salire and C. Pilson performed an annual FERC inspection of Anderson Dam and appurtenant structures. Also, collected manual VWPs readings of 21, 22, 23, and 24.

6.1 Other District Inspections

This section presents additional safety inspection by District staff focused on maintenance and monitoring issues. It should be noted that Dam Safety Program maintenance administrator Ron Jacobs inspects Leroy Anderson Dam monthly.

1. November 23, 2009, B. Baker and J. Nelson performed an ADAS upgrade which consisted of/swapping out IPI component module to accommodate warm up time.
2. December 22, 2009, B. Baker and J. Nelson collected manual IPIs readings and manual VWP readings of piezometers 9B, 10, 11, 12, and 13.
3. February 4, 2010 joint FERC and Division of Safety of Dams (DSOD) field trip to observe site conditions at 4 potential fault study sites for Anderson SSE1 including the Burnett, Turner, Rosenden Pond, and VTA sites. FERC personnel included B. O'keeffe and E. Salire, DSOD personnel included C. Dorsey, J. Lessman, and B. Fraser. AMEC personnel included T. Crampton and C. Slack. District personnel included M. Mooers and J. Nelson.
4. February 24, 2010 site visit to Anderson Dam to orient and train Post Earthquake Dam Assessment Program (PEDAP) volunteers. Dam Safety Unit personnel included D. Hook, B. Baker, S. Wu, and J. Nelson.
5. March 26, 2010 site visit to Anderson Dam to orient and train outside local emergency response agencies to District's PEDAP. Dam Safety Unit personnel included D. Hook, S. Wu, and J. Nelson.
6. May 21, 2010, B. Baker and J. Nelson performed site visit to check non-functional ADAS and take manual readings of VWPs 1, 2, 3, 4, 9B, 10, 11, 12, 13, 21, 22, 23, and 24.
7. June 3, 2010, B. Baker performed site visit to replace VWT module for VWPs.
8. July 21, 2010, B. Baker and J. Nelson performed site visit to check non-functional ADAS and take manual readings of all IPIs and VWPs 1, 2, 3, 4, 5, 6, 19 and 20.
9. October 25, 2010 site visit to collect manual readings of all IPIs and VWPs 1, 2, 3, 4, 19, 20, 21, 22, 23, and 24.
10. November 17, 2010 site visit by M. Mooers, B. Baker, and J. Nelson to observe AMEC (C. Slack, and B. Gray) fault trench at Turner property.
11. November 19, 2010 site visit by J. Nelson to observe AMEC (C. Slack, and B. Gray) fault trench at Turner property.
12. December 2, 2010 site visit to observe AMEC fault trench at Turner property. District personnel included F. Maitski, D. Hook, S. Wu, M. Mooers, D. Matthews. AMEC personnel included T. Crampton, C. Slack, and B. Gray. WLA personnel included K. Kelson and J. Pearce. Technical Review Board included L. Cluff.
13. December 9, 2010 site visit by J. Nelson to observe newly excavated eastward extension of AMEC fault trench at Turner property.

7.0 SURVEILLANCE PROGRAM

For the period of January 2010 to December 2010, no significant modifications of the dam or appurtenant structures occurred that would impact the surveillance data or its interpretation.

The District will continue with the current operating procedures and scheduled surveillance plans. Pneumatic and open well piezometers will be read monthly, crest and spillway training wall monuments will be surveyed annually, and spillway underdrain flows will be measured at the two weirs at least monthly. ADAS instrumentation (vibrating wire piezometers) will be read daily. In-place inclinometer sensors (IPIs) will be collected manually on a quarterly basis until ADAS issues are resolved. In addition, site inspections and monument surveys will be conducted after a significant earthquake or other potentially disruptive activity.

While most of the instruments are in good working order, some ADAS related problems exist, which the District will address in 2011. Due to ongoing power supply issues there are significant data gaps with durations of 2 months to 14 months for 7 VWPs (1, 2, 3, 19, 22, 23, and 24). The District is currently working to resolve the power issues in early 2011, which will result in continuous data readings from the 7 VWPs. The District will keep DSOD apprised of this work. Aside from efforts to repair ADAS and IPIs issues, we do not anticipate major replacement or repair work in 2011.

Although there were no major incidents or changes at the dam during 2010, an operating restriction for Anderson Reservoir (~elev. 590.8 ft) was implemented under the approval of the Division of Safety of Dams and concurrence of FERC, and monitored by District Operations and Planning Unit beginning in October 2010 that supersedes the earlier January 2009 restriction (~elev. 607.8 ft). This operating restriction was implemented to provide an added margin of safety in response to preliminary seismic stability results for Anderson Dam. Except for the new operating restriction at Anderson Reservoir of ~57 feet total freeboard, there are no substantive changes in dam or reservoir response compared to previous years.

8.0 OTHER INFORMATION

8.1 Recent Engineering Analyses

AMEC is currently finalizing a detailed seismic safety evaluation (SSE1A) of Anderson Dam with a final report due by May, 2011.

9.0 CONCLUSIONS

AMEC’s 2010 preliminary SSE1A findings based on substantial geotechnical data confirmed the earlier report, which indicated a potentially inadequate factor of seismic safety for Anderson Dam. In response to the findings of that report, the District implemented a voluntary operating restriction to ~elev. 590.8 ft which is ~57 feet below the Dam crest. The new restriction supersedes the 2009 restriction of ~elev. 607.8 ft.

The surveillance data from Anderson Dam and the District’s field observations confirm acceptable performance of the dam for the period of this report, with the dam showing normal responses to the environment, aging process, and external events. During the period of this report there were no surveillance instrumentation alarm conditions. The District will continue with the current monitoring program and safety inspections, and will keep DSOD informed of any significant changes pertaining to the surveillance or performance of Leroy Anderson Dam.

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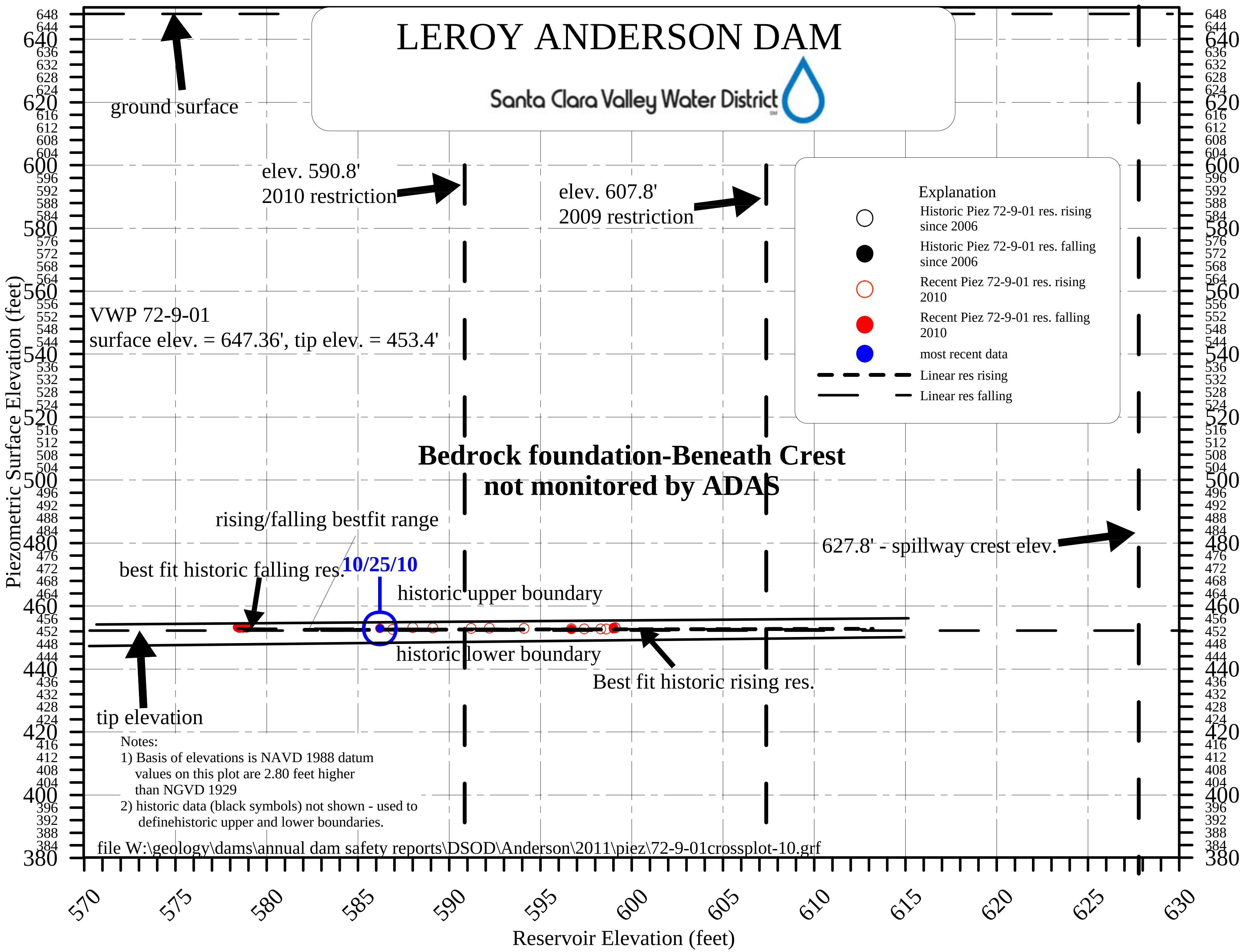
Appendix A – Piezometer & Weir Cross Plots

Figures A-1 through A-31 Cross Plots of Reservoir Elevations versus Vibrating Wire Piezometric Surface Elevations

Figures A-32 and A-33 Cross Plots of Reservoir Elevations versus Pneumatic Piezometric Surface Elevations

Figures A-34 through A-36 Cross Plots of Reservoir Elevations versus Open Well Piezometric Surface Elevations

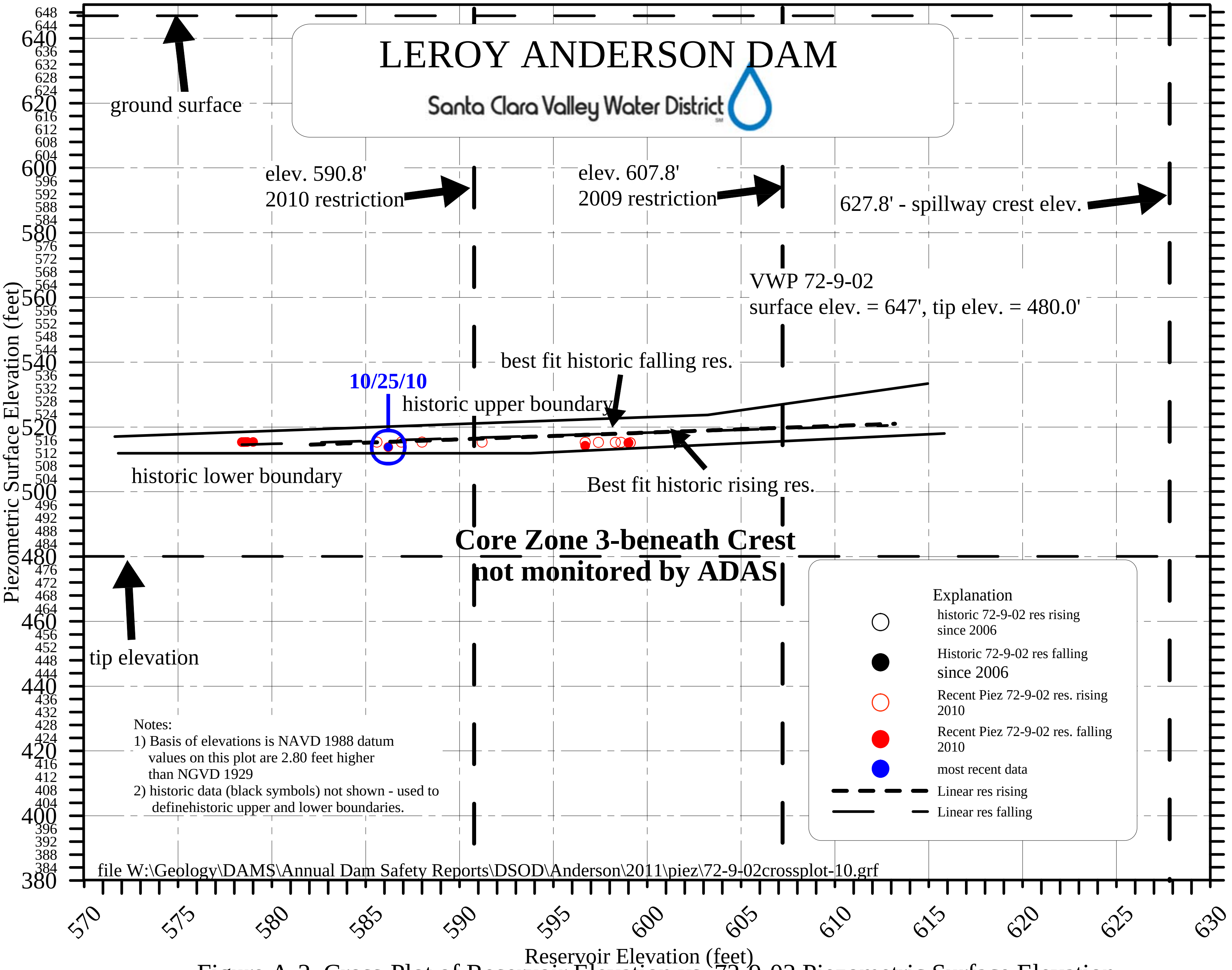
Figure A-37 Cross Plot of Reservoir Elevation versus Spillway Weir Discharge, gpm



Notes:
1) Basis of elevations is NAVD 1988 datum
values on this plot are 2.80 feet higher
than NGVD 1929
2) historic data (black symbols) not shown - used to
definehistoric upper and lower boundaries.

file W:\geology\dams\annual dam safety reports\DSOD\Anderson\2011\piez\72-9-01crossplot-10.grf

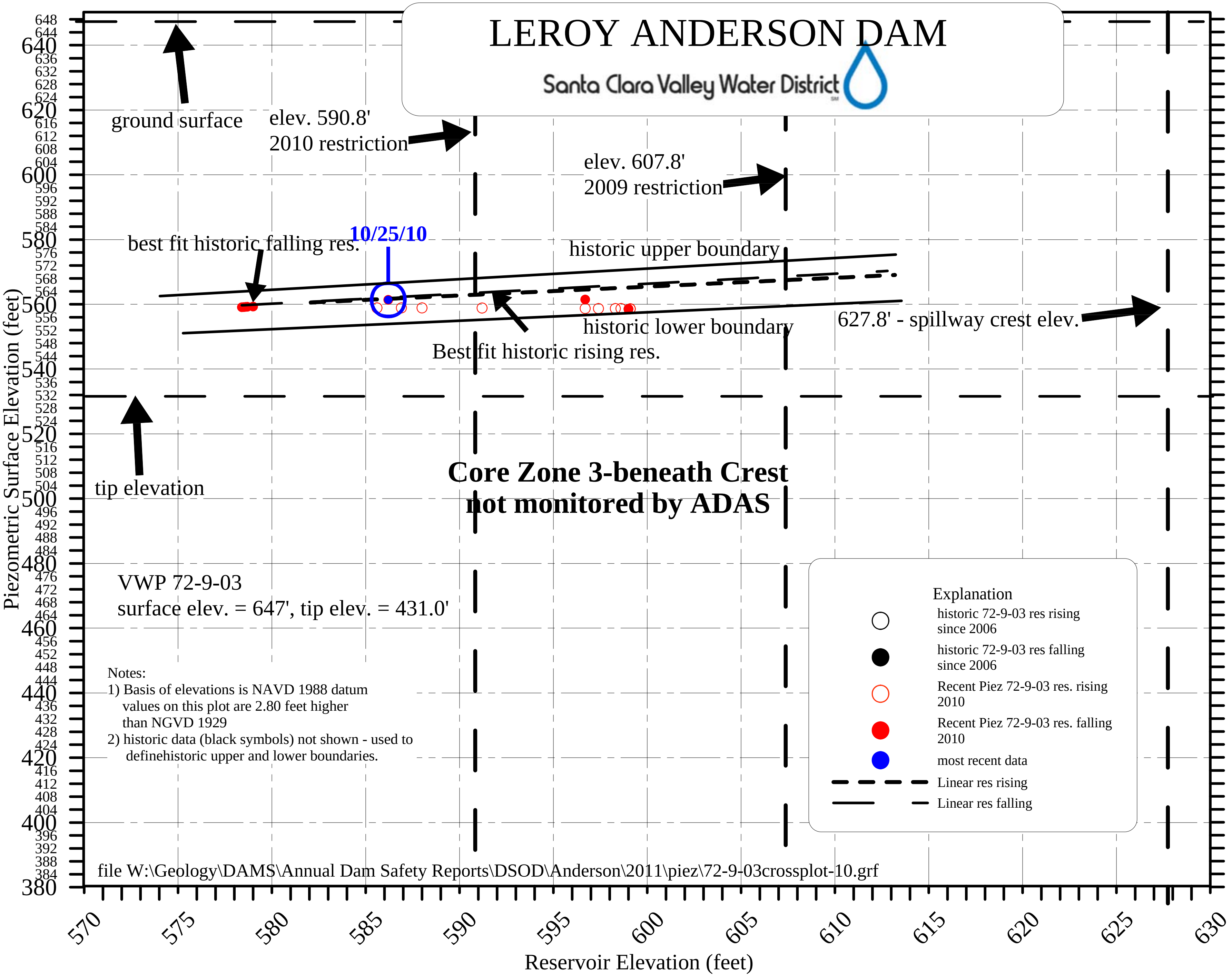
Figure A-1. Cross-Plot of Reservoir Elevation vs. 72-9-01 Piezometric Surface Elevation



Notes:
1) Basis of elevations is NAVD 1988 datum values on this plot are 2.80 feet higher than NGVD 1929
2) historic data (black symbols) not shown - used to definehistoric upper and lower boundaries.

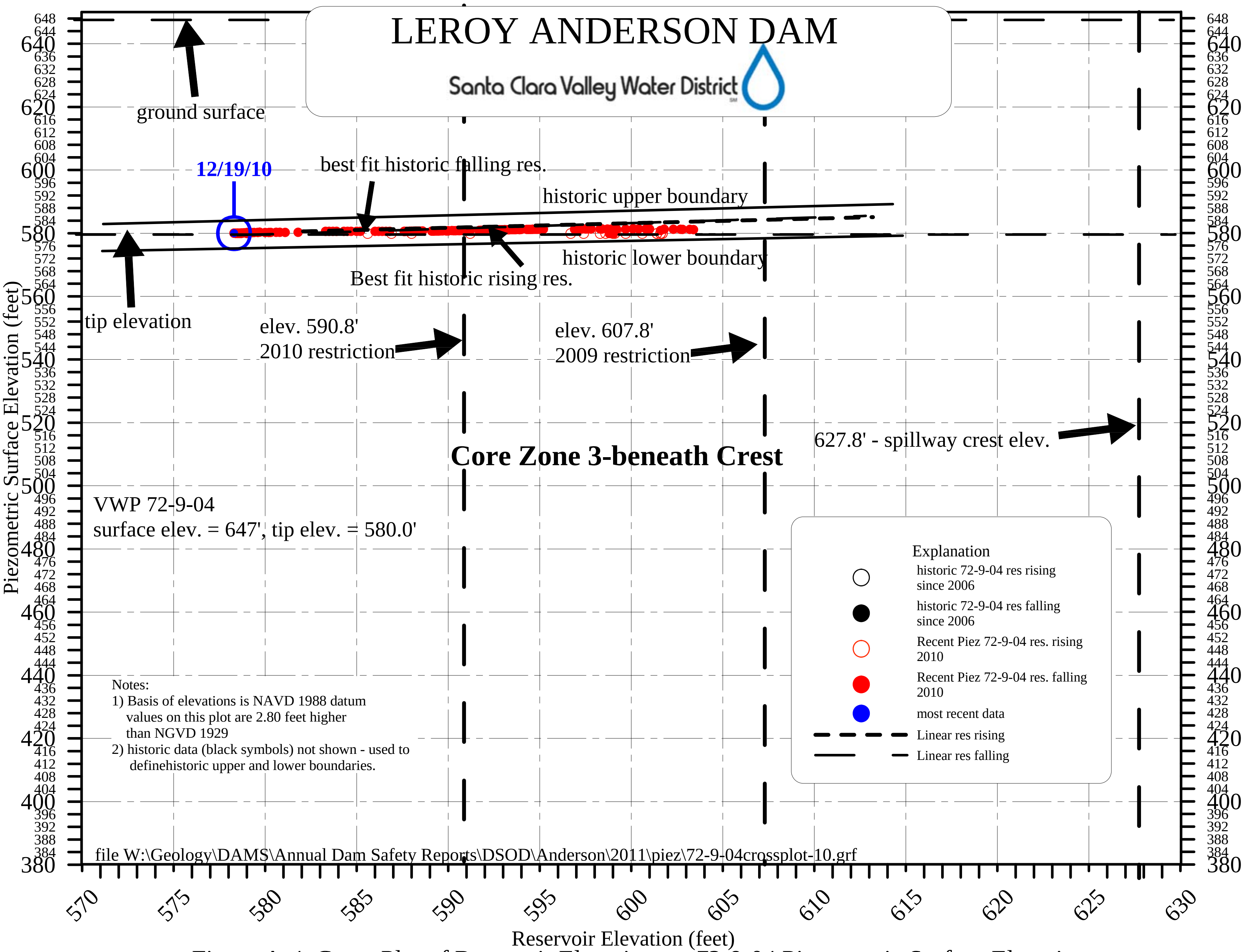
file W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\Anderson\2011\piez\72-9-02crossplot-10.grf

Figure A-2. Cross-Plot of Reservoir Elevation vs. 72-9-02 Piezometric Surface Elevation



Notes:
1) Basis of elevations is NAVD 1988 datum values on this plot are 2.80 feet higher than NGVD 1929
2) historic data (black symbols) not shown - used to definehistoric upper and lower boundaries.

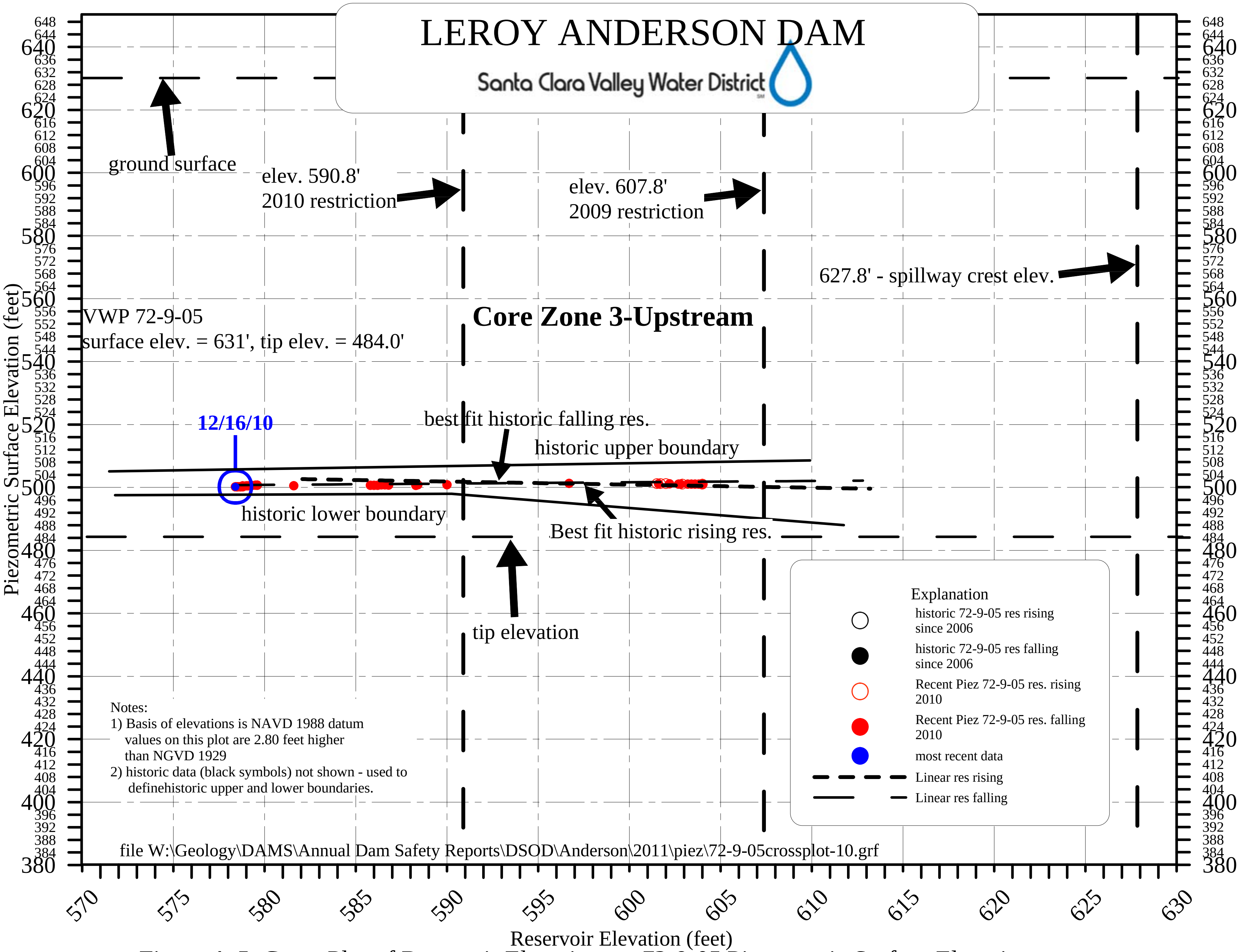
Figure A-3. Cross-Plot of Reservoir Elevation vs. 72-9-03 Piezometer Data



Notes:
1) Basis of elevations is NAVD 1988 datum values on this plot are 2.80 feet higher than NGVD 1929
2) historic data (black symbols) not shown - used to definehistoric upper and lower boundaries.

file W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\Anderson\2011\piez\72-9-04crossplot-10.grf

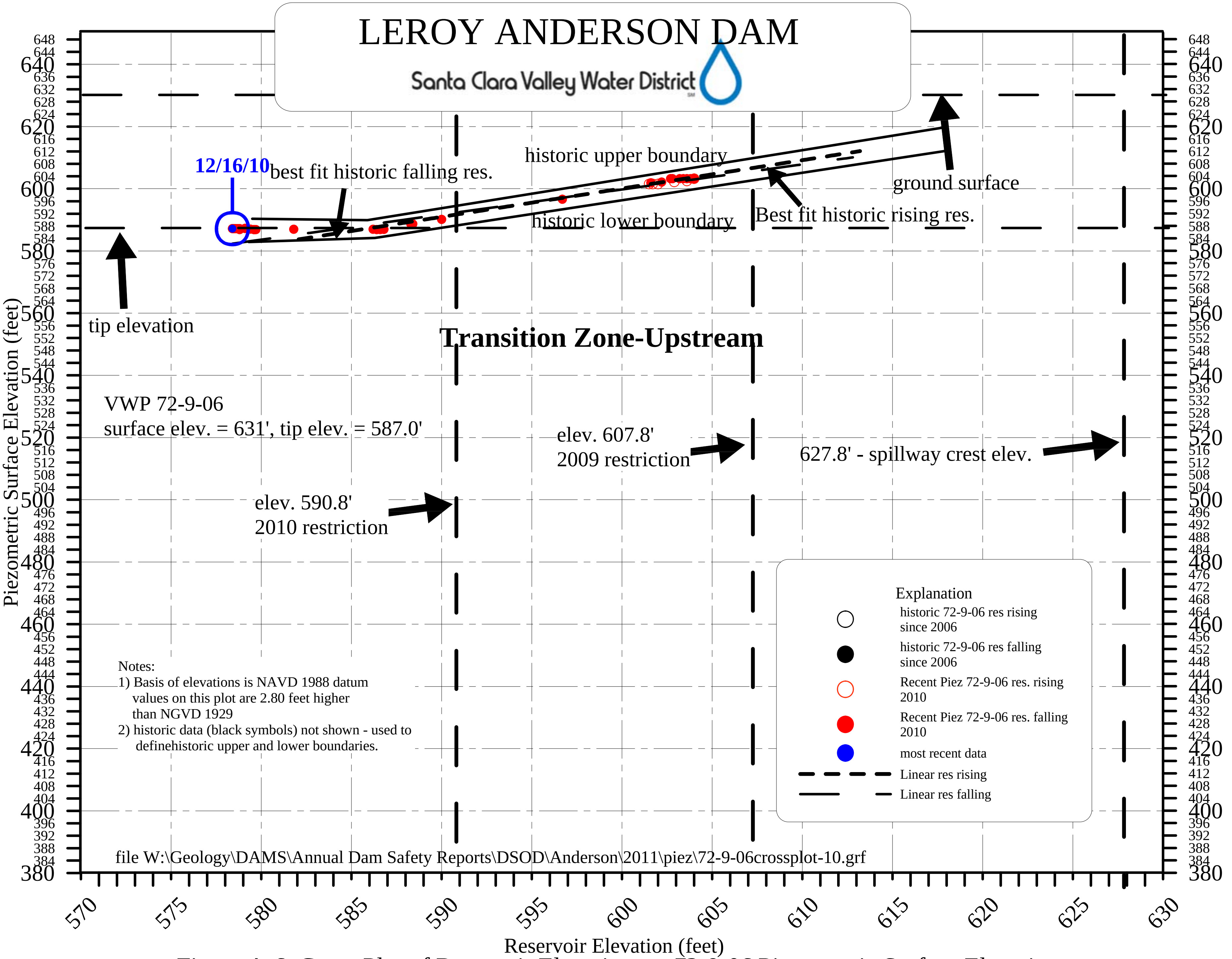
Figure A-4. Cross-Plot of Reservoir Elevation vs. 72-9-04 Piezometric Surface Elevation



Notes:
1) Basis of elevations is NAVD 1988 datum values on this plot are 2.80 feet higher than NGVD 1929
2) historic data (black symbols) not shown - used to definehistoric upper and lower boundaries.

file W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\Anderson\2011\piez\72-9-05crossplot-10.grf

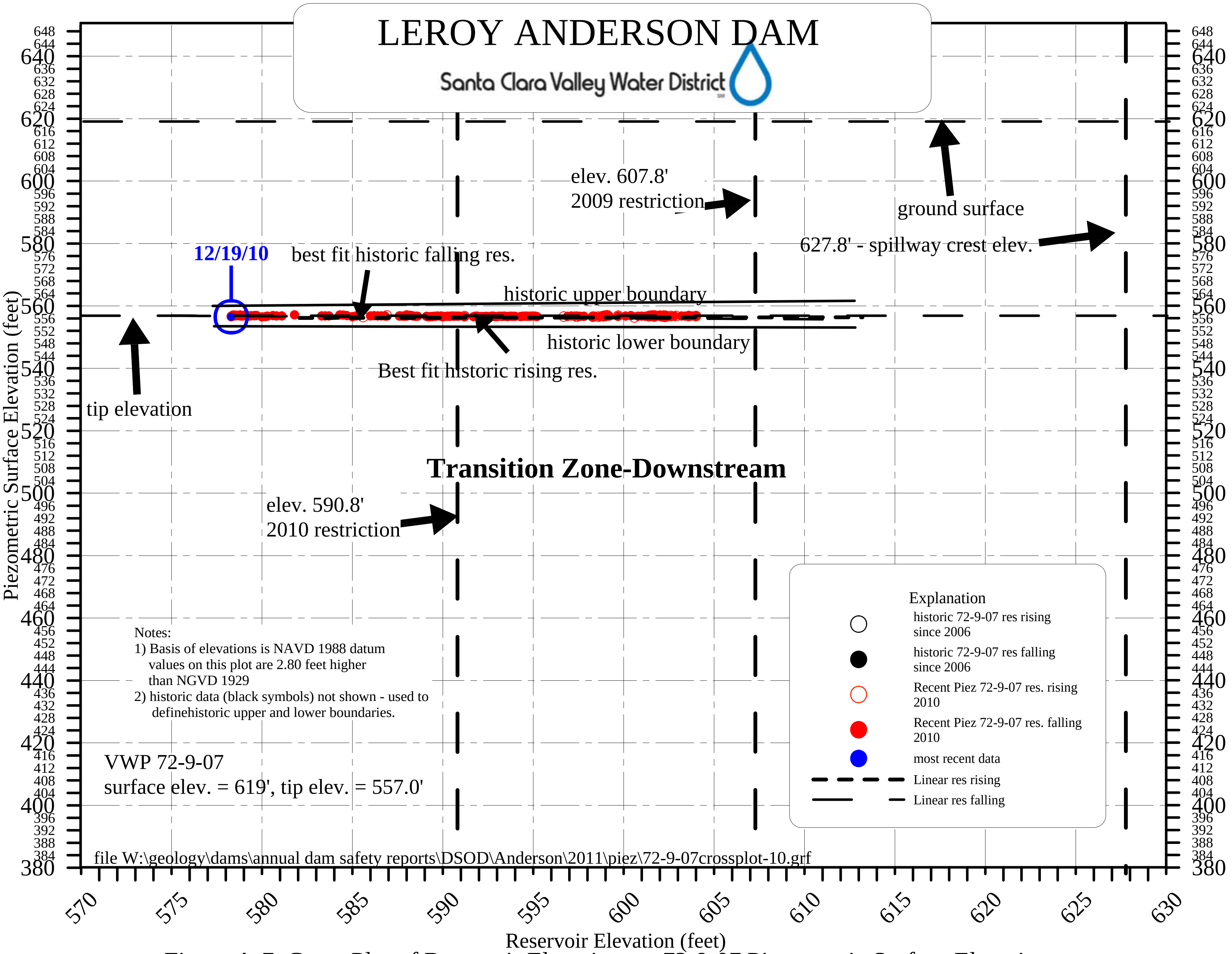
Figure A-5. Cross-Plot of Reservoir Elevation vs. 72-9-05 Piezometric Surface Elevation



Notes:
1) Basis of elevations is NAVD 1988 datum values on this plot are 2.80 feet higher than NGVD 1929
2) historic data (black symbols) not shown - used to definehistoric upper and lower boundaries.

file W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\Anderson\2011\piez\72-9-06crossplot-10.grf

Figure A-6. Cross-Plot of Reservoir Elevation vs. 72-9-06 Piezometric Surface Elevation

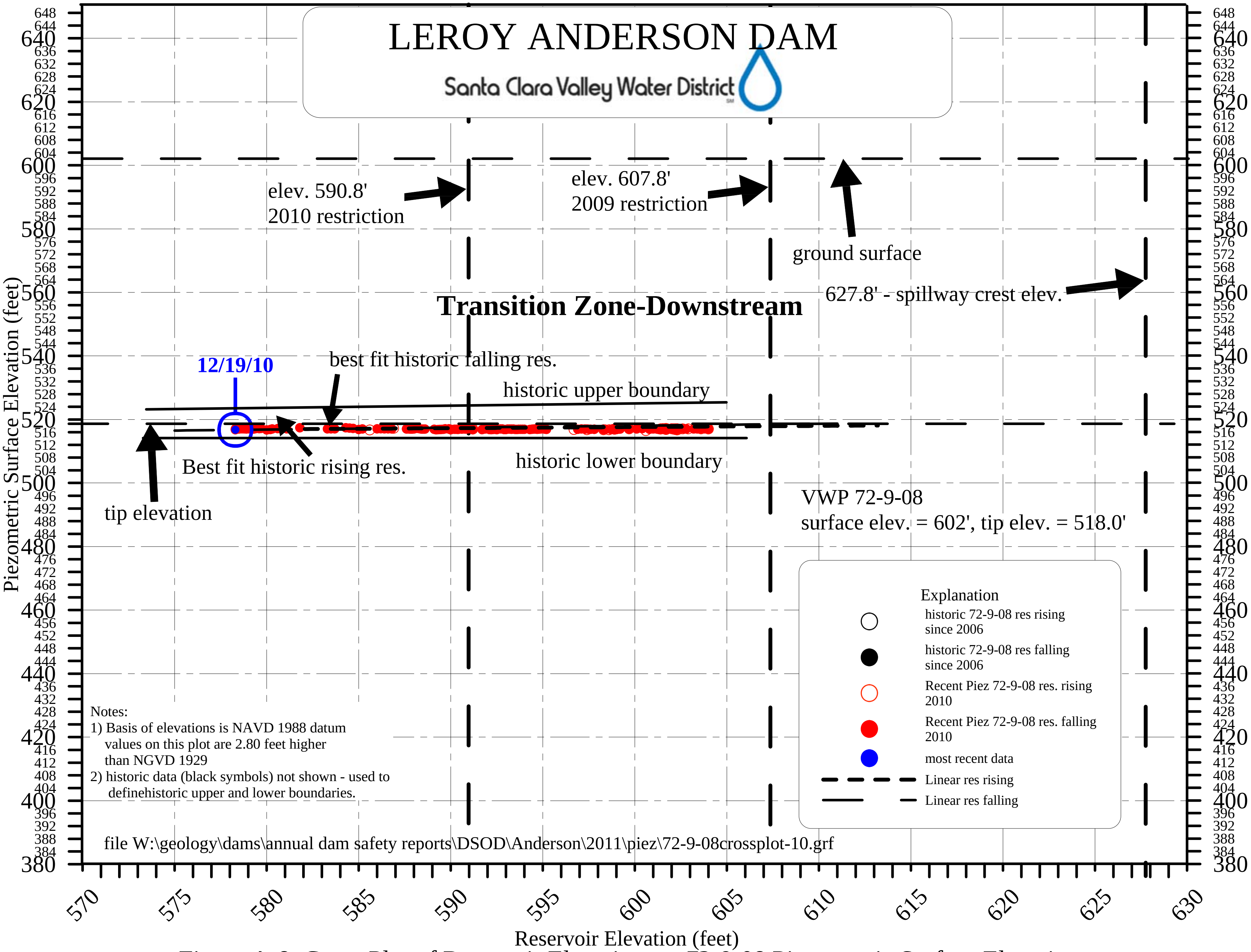


Notes:
1) Basis of elevations is NAVD 1988 datum values on this plot are 2.80 feet higher than NGVD 1929
2) historic data (black symbols) not shown - used to definehistoric upper and lower boundaries.

VWP 72-9-07
surface elev. = 619', tip elev. = 557.0'

file W:\geology\dams\annual dam safety reports\DSOD\Anderson\2011\piez\72-9-07crossplot-10.grf

Figure A-7. Cross-Plot of Reservoir Elevation vs. 72-9-07 Piezometric Surface Elevation


LEROY ANDERSON DAM

Santa Clara Valley Water District

Transition Zone-Downstream

elev. 590.8'
2010 restriction

elev. 607.8'
2009 restriction

ground surface

627.8' - spillway crest elev.

12/19/10

best fit historic falling res.

historic upper boundary

Best fit historic rising res.

historic lower boundary

tip elevation

VWP 72-9-08
surface elev. = 602', tip elev. = 518.0'

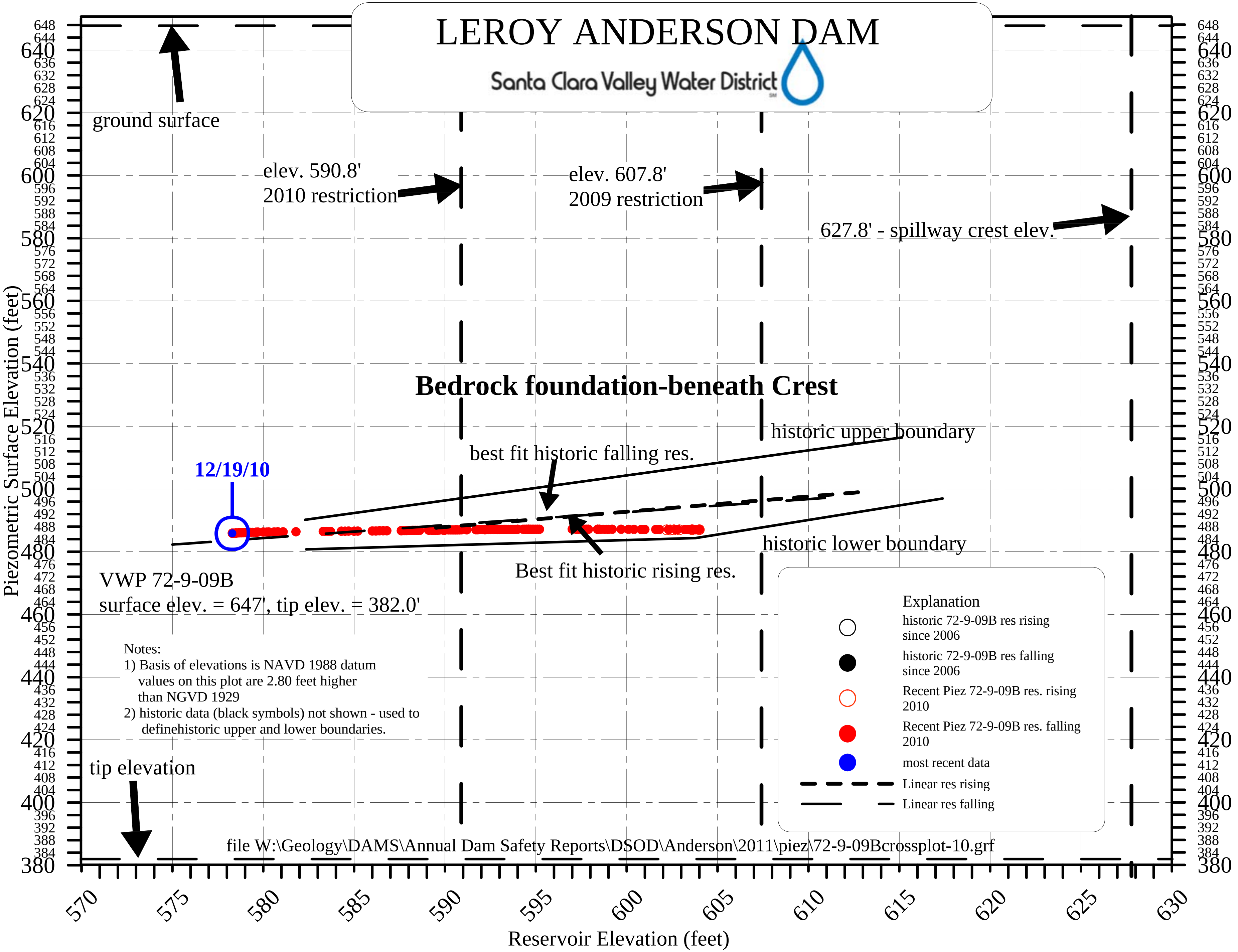
Explanation

○	historic 72-9-08 res rising since 2006
●	historic 72-9-08 res falling since 2006
○	Recent Piez 72-9-08 res. rising 2010
●	Recent Piez 72-9-08 res. falling 2010
●	most recent data
– – –	Linear res rising
—— —	Linear res falling

Notes:
1) Basis of elevations is NAVD 1988 datum values on this plot are 2.80 feet higher than NGVD 1929
2) historic data (black symbols) not shown - used to definehistoric upper and lower boundaries.

file W:\geology\dams\annual dam safety reports\DSOD\Anderson\2011\piez\72-9-08crossplot-10.grf

Figure A-8. Cross-Plot of Reservoir Elevation vs. 72-9-08 Piezometric Surface Elevation



Notes:
1) Basis of elevations is NAVD 1988 datum values on this plot are 2.80 feet higher than NGVD 1929
2) historic data (black symbols) not shown - used to definehistoric upper and lower boundaries.

Figure A-9. Cross-Plot of Reservoir Elevation vs. 72-9-09B Piezometric Surface Elevation

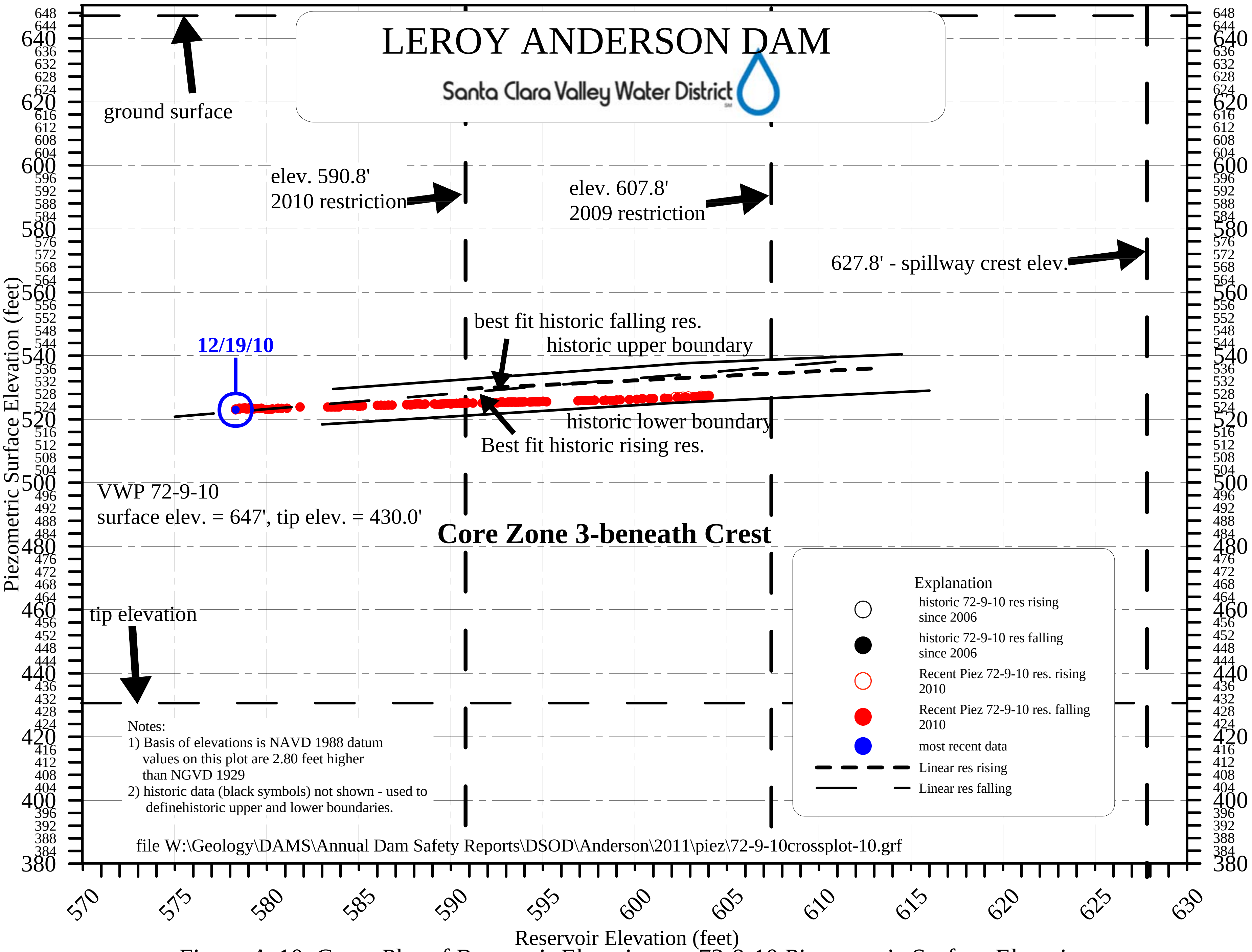


Figure A-10. Cross-Plot of Reservoir Elevation vs. 72-9-10 Piezometric Surface Elevation

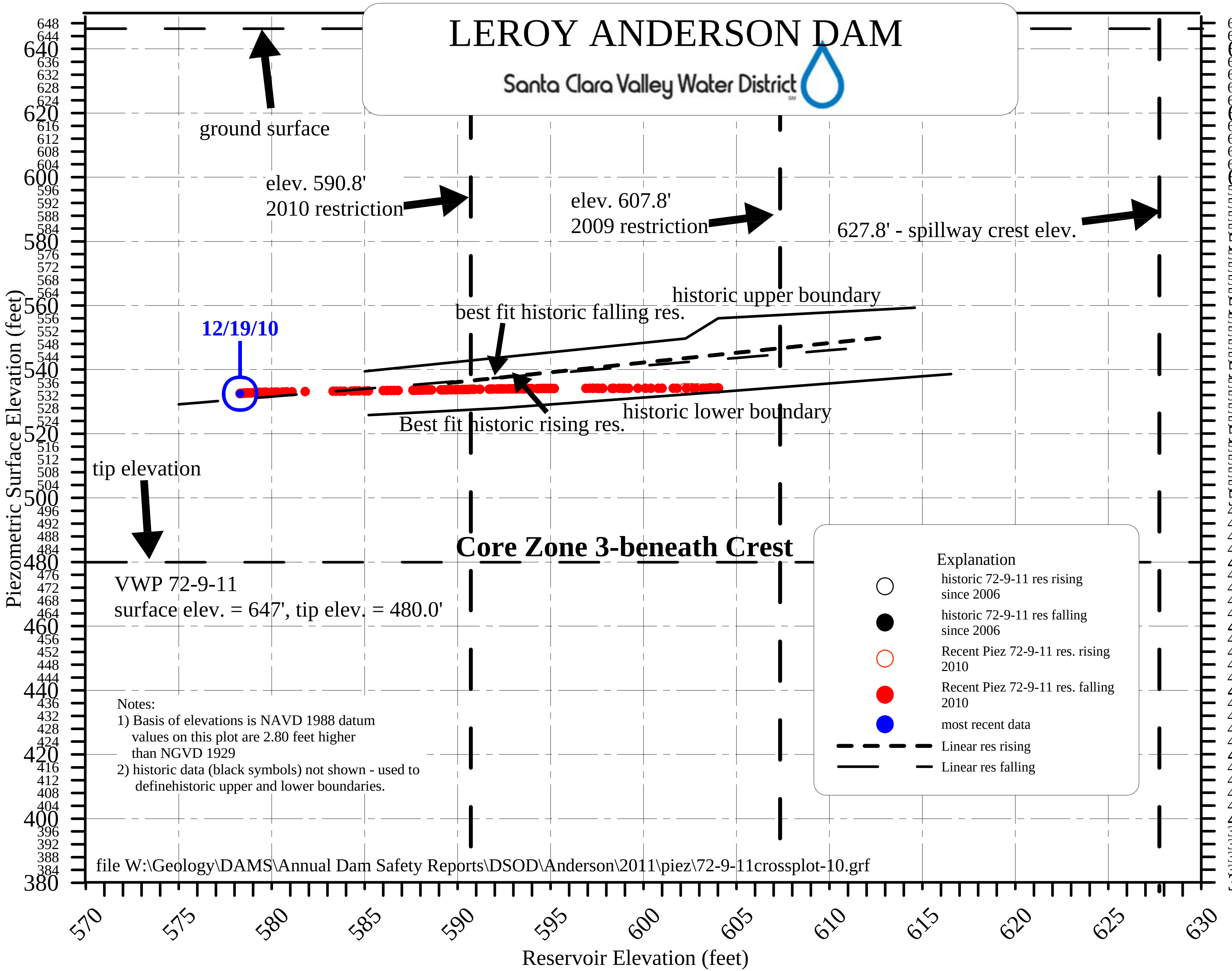
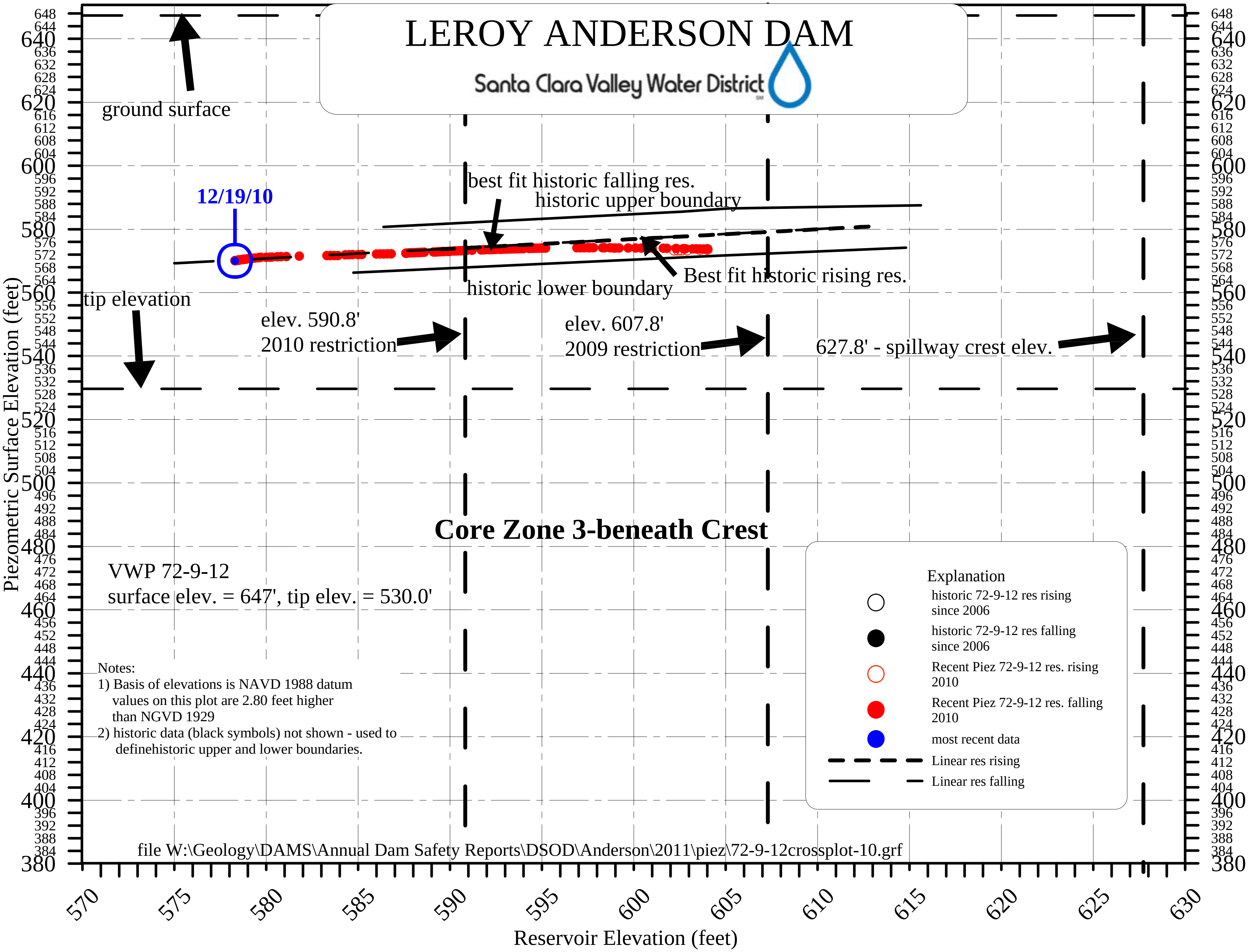
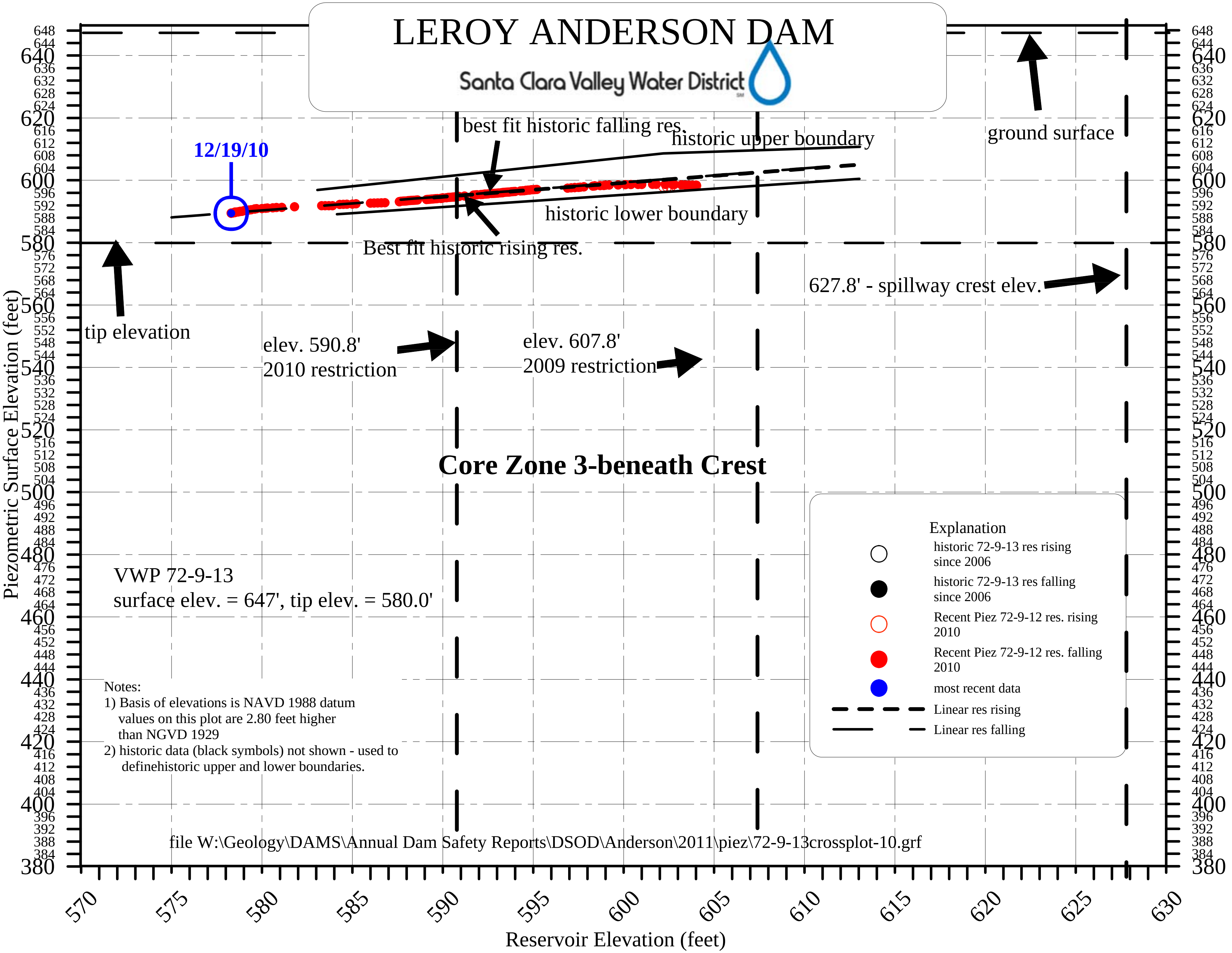


Figure A-11. Cross-Plot of Reservoir Elevation vs. 72-9-11 Piezometric Surface Elevation



Notes:
1) Basis of elevations is NAVD 1988 datum values on this plot are 2.80 feet higher than NGVD 1929
2) historic data (black symbols) not shown - used to definehistoric upper and lower boundaries.

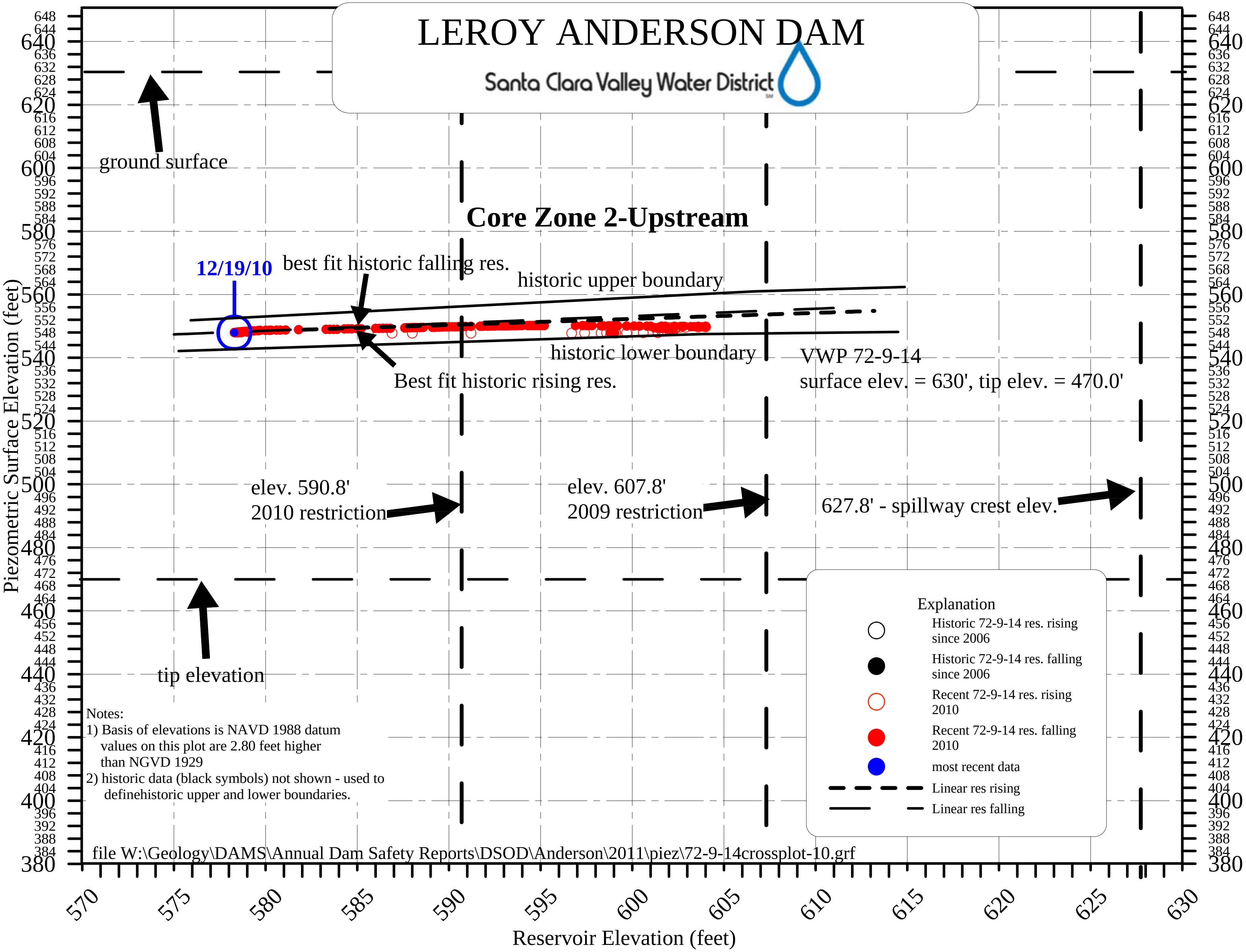
Figure A-12. Cross-Plot of Reservoir Elevation vs. 72-9-12 Piezometric Surface Elevation



Notes:
1) Basis of elevations is NAVD 1988 datum values on this plot are 2.80 feet higher than NGVD 1929
2) historic data (black symbols) not shown - used to definehistoric upper and lower boundaries.

file W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\Anderson\2011\piez\72-9-13crossplot-10.grf

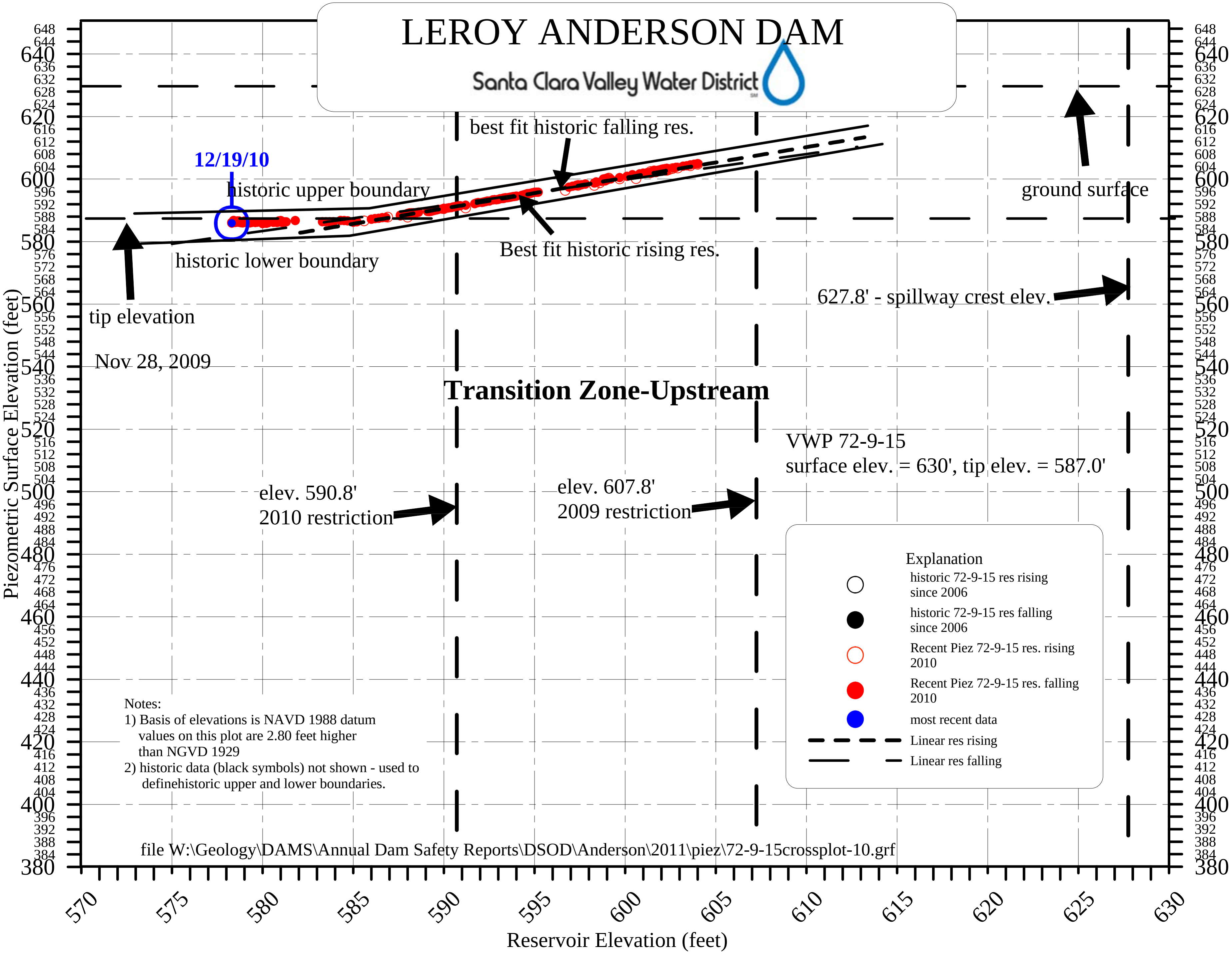
Figure A-13. Cross-Plot of Reservoir Elevation vs. 72-9-13 Piezometric Surface Elevation



Notes:
1) Basis of elevations is NAVD 1988 datum values on this plot are 2.80 feet higher than NGVD 1929
2) historic data (black symbols) not shown - used to definehistoric upper and lower boundaries.

file W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\Anderson\2011\piez\72-9-14crossplot-10.grf

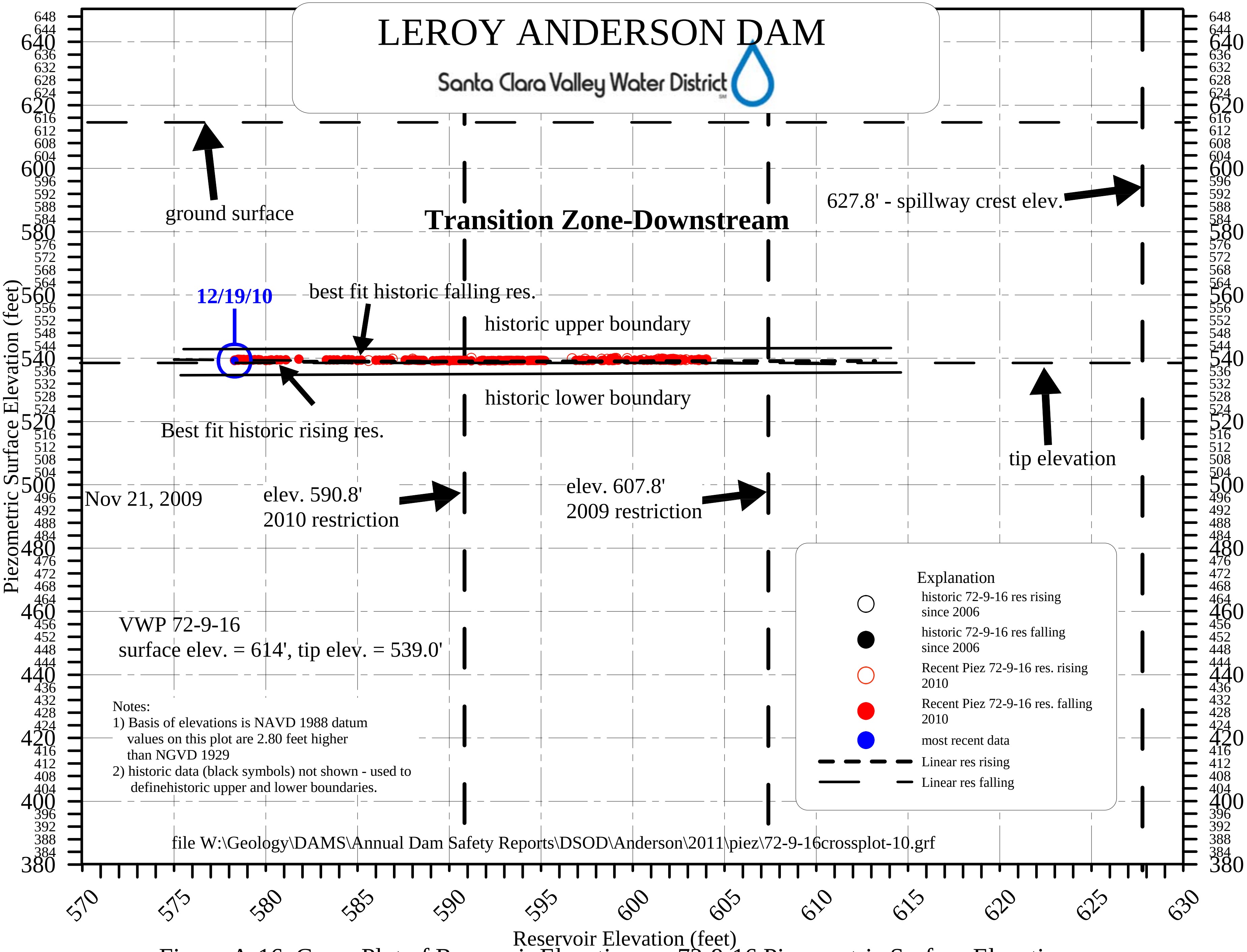
Figure A-14. Cross-Plot of Reservoir Elevation vs. 72-9-14 Piezometric Surface Elevation



Notes:
1) Basis of elevations is NAVD 1988 datum values on this plot are 2.80 feet higher than NGVD 1929
2) historic data (black symbols) not shown - used to definehistoric upper and lower boundaries.

file W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\Anderson\2011\piez\72-9-15crossplot-10.grf

Figure A-15. Cross-Plot of Reservoir Elevation vs. 72-9-15 Piezometric Surface Elevation



VWP 72-9-16
surface elev. = 614', tip elev. = 539.0'

Notes:
1) Basis of elevations is NAVD 1988 datum values on this plot are 2.80 feet higher than NGVD 1929
2) historic data (black symbols) not shown - used to definehistoric upper and lower boundaries.

file W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\Anderson\2011\piez\72-9-16crossplot-10.grf

Figure A-16. Cross-Plot of Reservoir Elevation vs. 72-9-16 Piezometric Surface Elevation

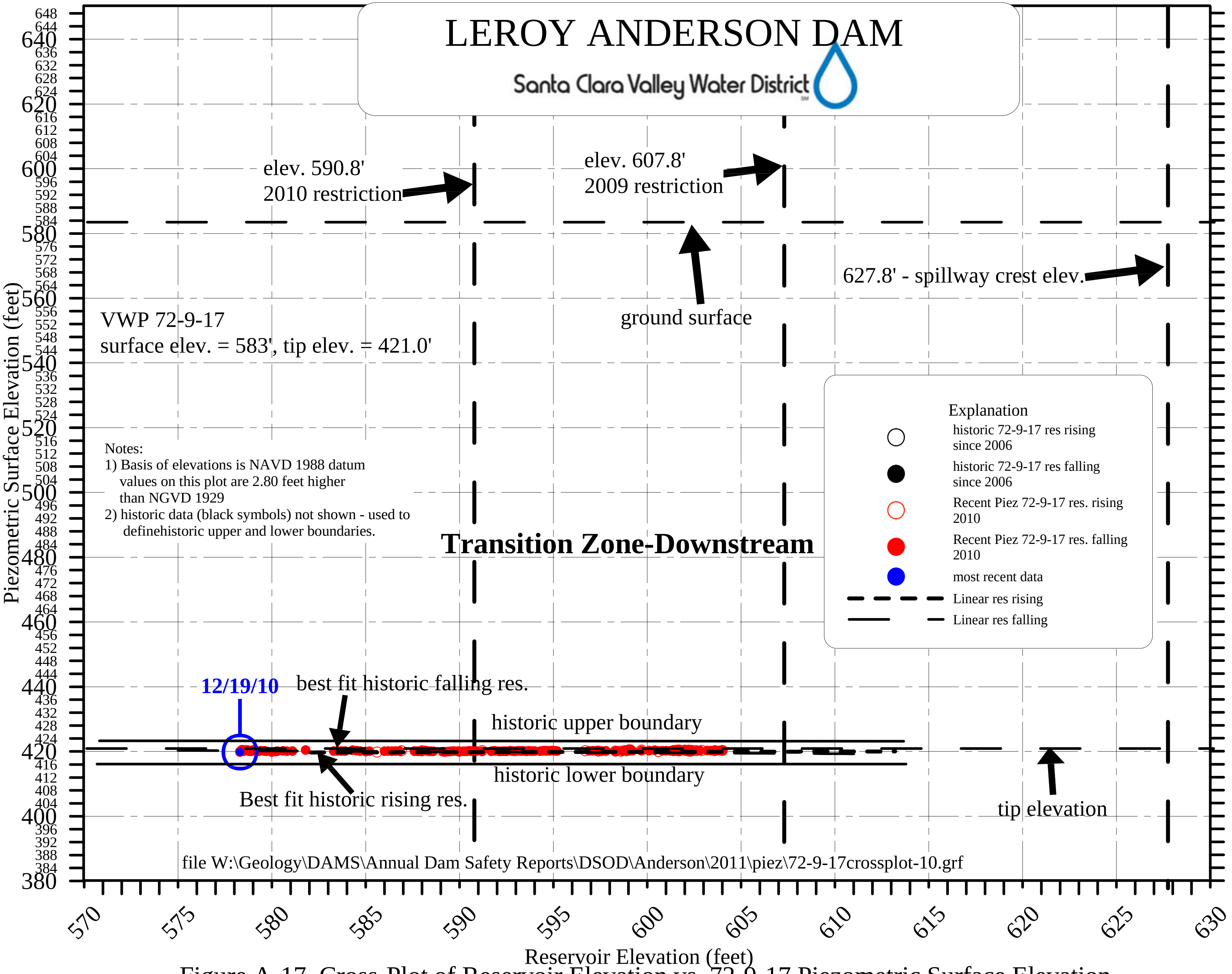
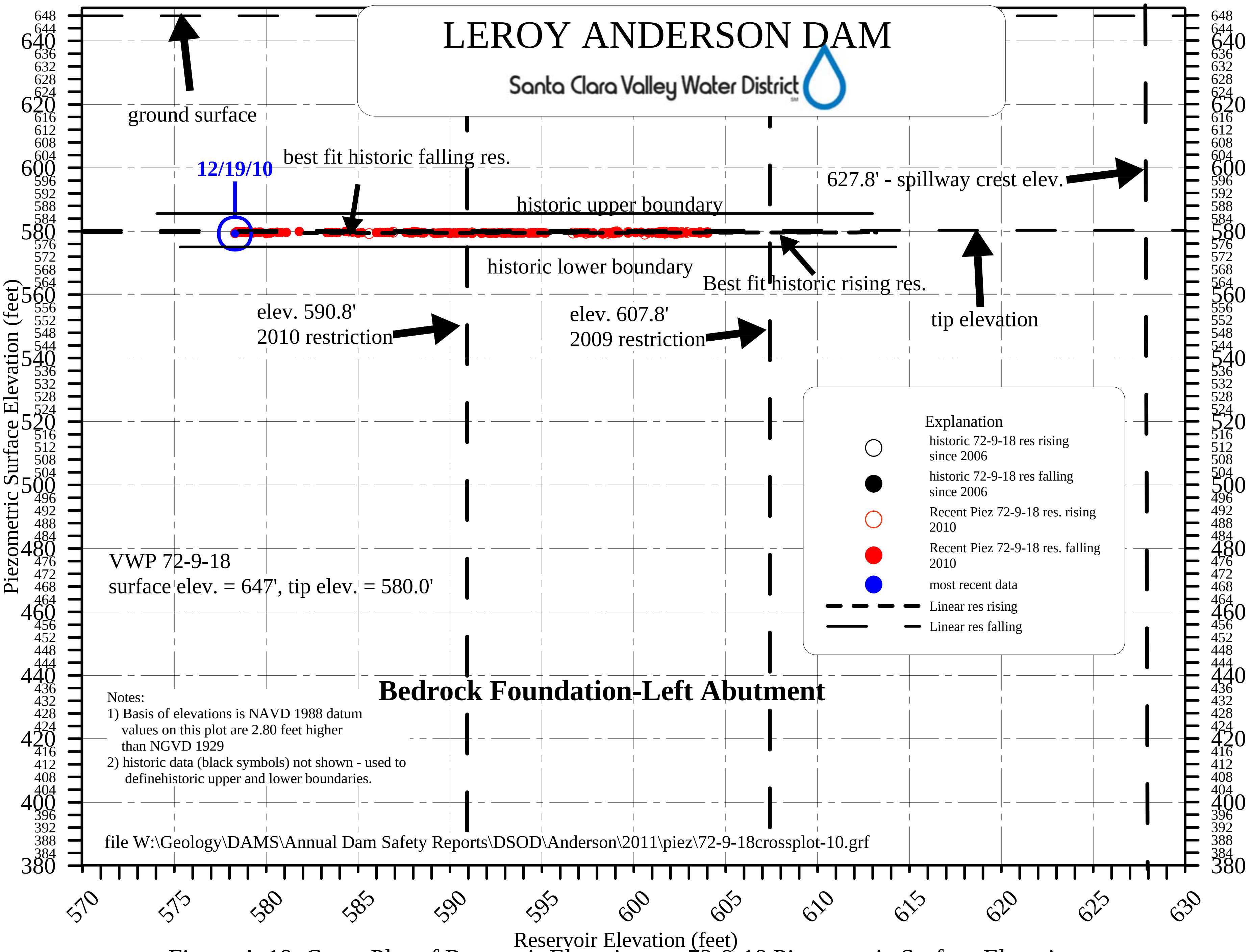


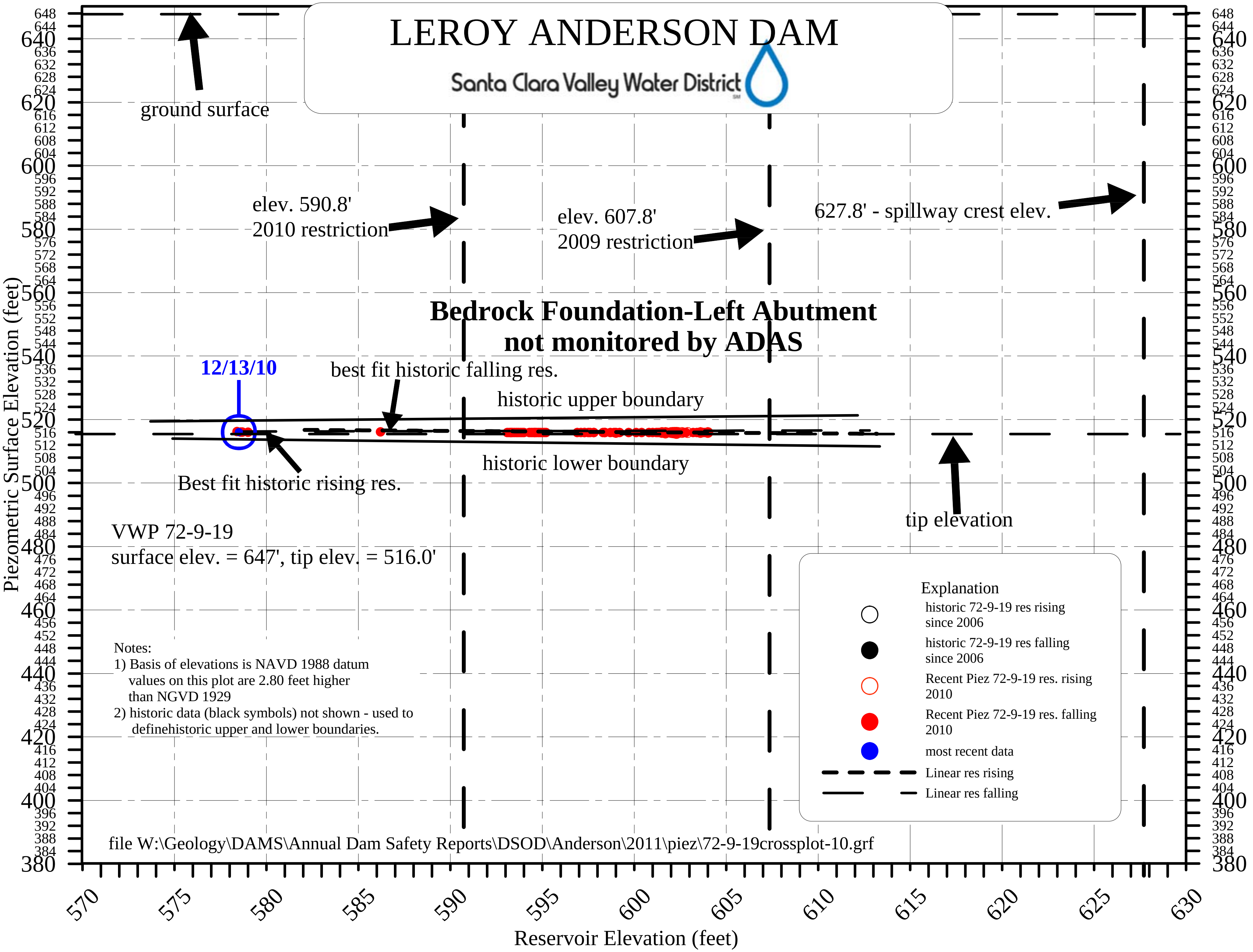
Figure A-17. Cross-Plot of Reservoir Elevation vs. 72-9-17 Piezometric Surface Elevation



Notes:
1) Basis of elevations is NAVD 1988 datum values on this plot are 2.80 feet higher than NGVD 1929
2) historic data (black symbols) not shown - used to definehistoric upper and lower boundaries.

file W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\Anderson\2011\piez\72-9-18crossplot-10.grf

Figure A-18. Cross-Plot of Reservoir Elevation vs. 72-9-18 Piezometric Surface Elevation



Notes:
1) Basis of elevations is NAVD 1988 datum
values on this plot are 2.80 feet higher
than NGVD 1929
2) historic data (black symbols) not shown - used to
definehistoric upper and lower boundaries.

file W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\Anderson\2011\piez\72-9-19crossplot-10.grf

Figure A-19. Cross-Plot of Reservoir Elevation vs. 72-9-19 Piezometric Surface Elevation

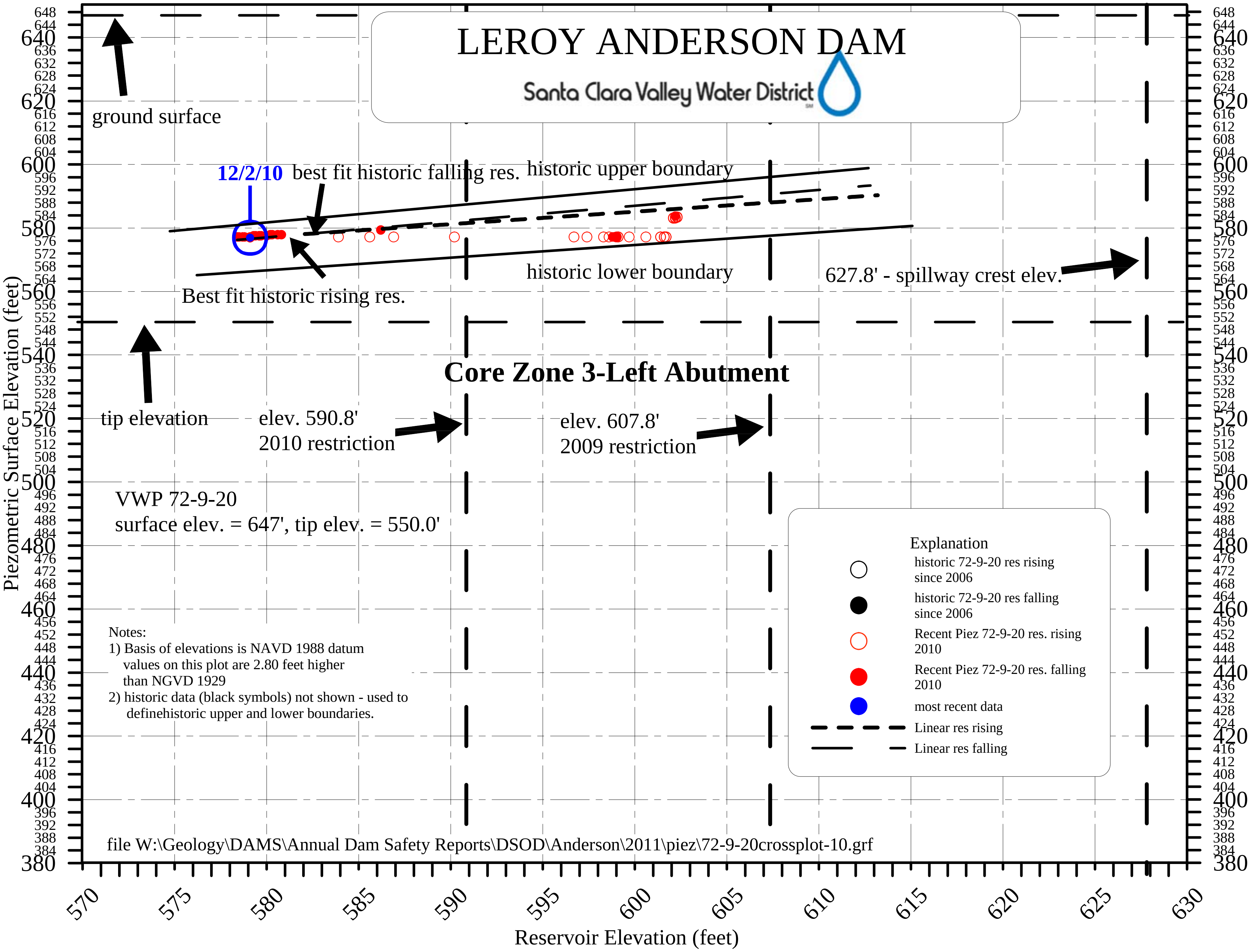
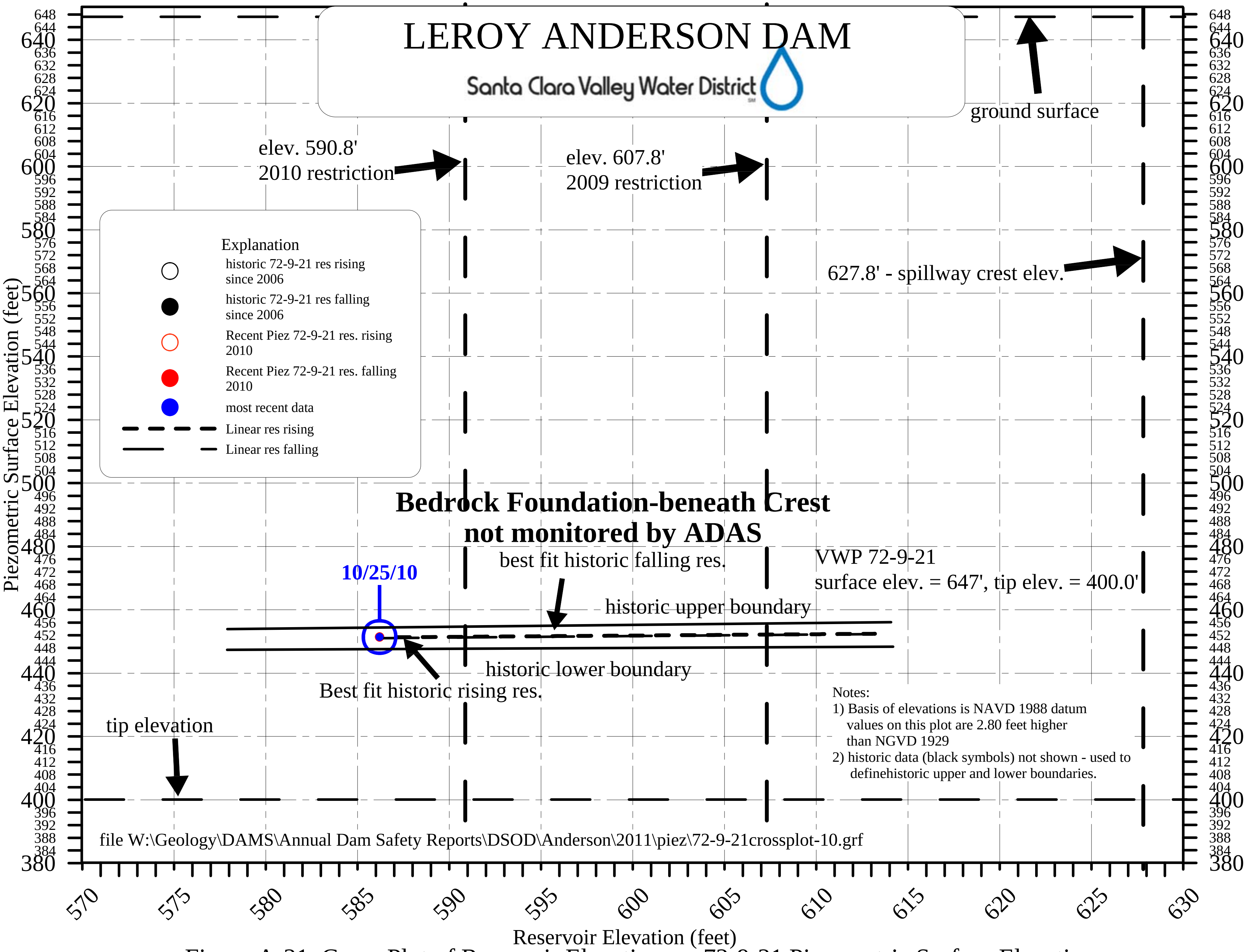


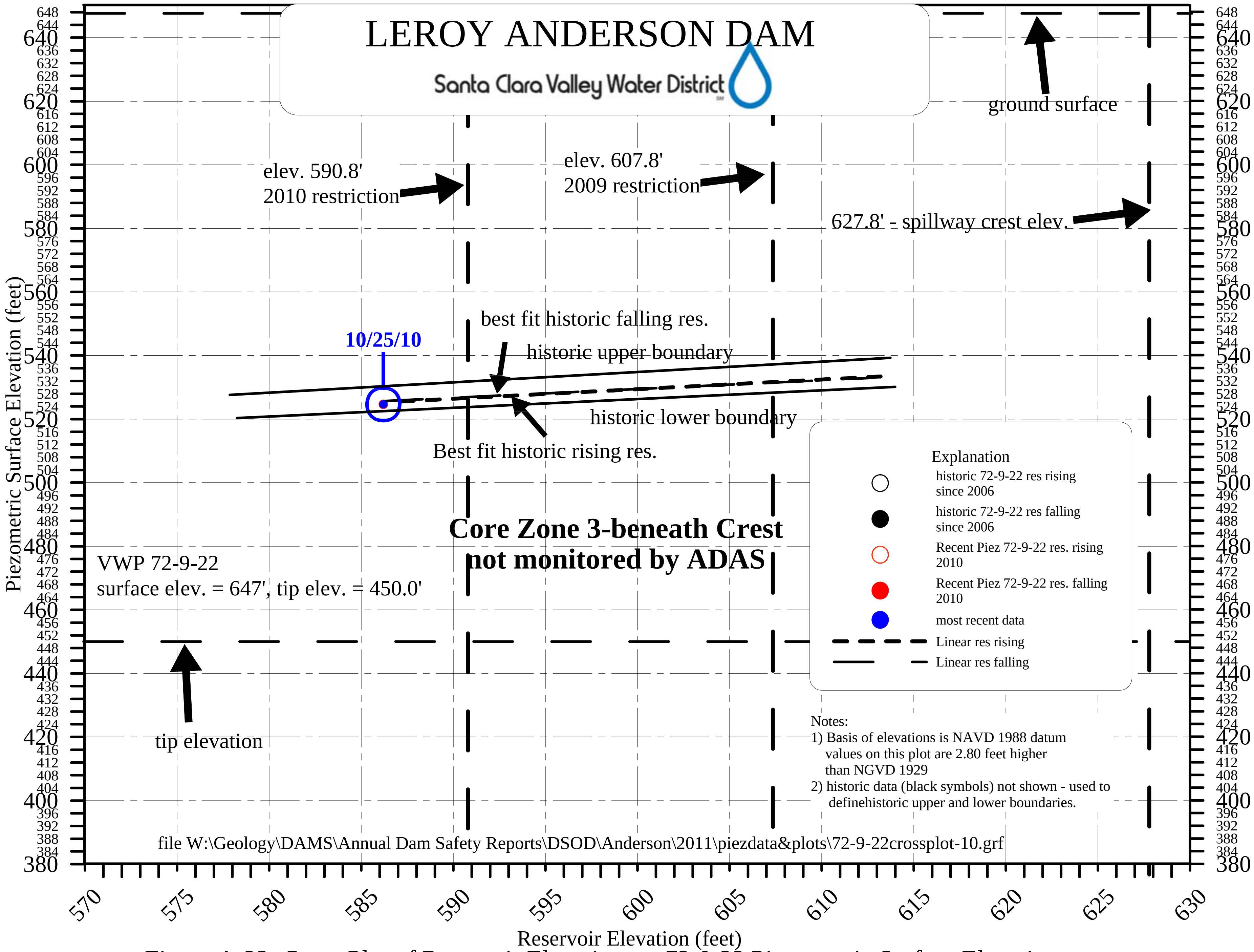
Figure A-20. Cross-Plot of Reservoir Elevation vs. 72-9-20 Piezometric Surface Elevation



Notes:
1) Basis of elevations is NAVD 1988 datum values on this plot are 2.80 feet higher than NGVD 1929
2) historic data (black symbols) not shown - used to definehistoric upper and lower boundaries.

file W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\Anderson\2011\piez\72-9-21crossplot-10.grf

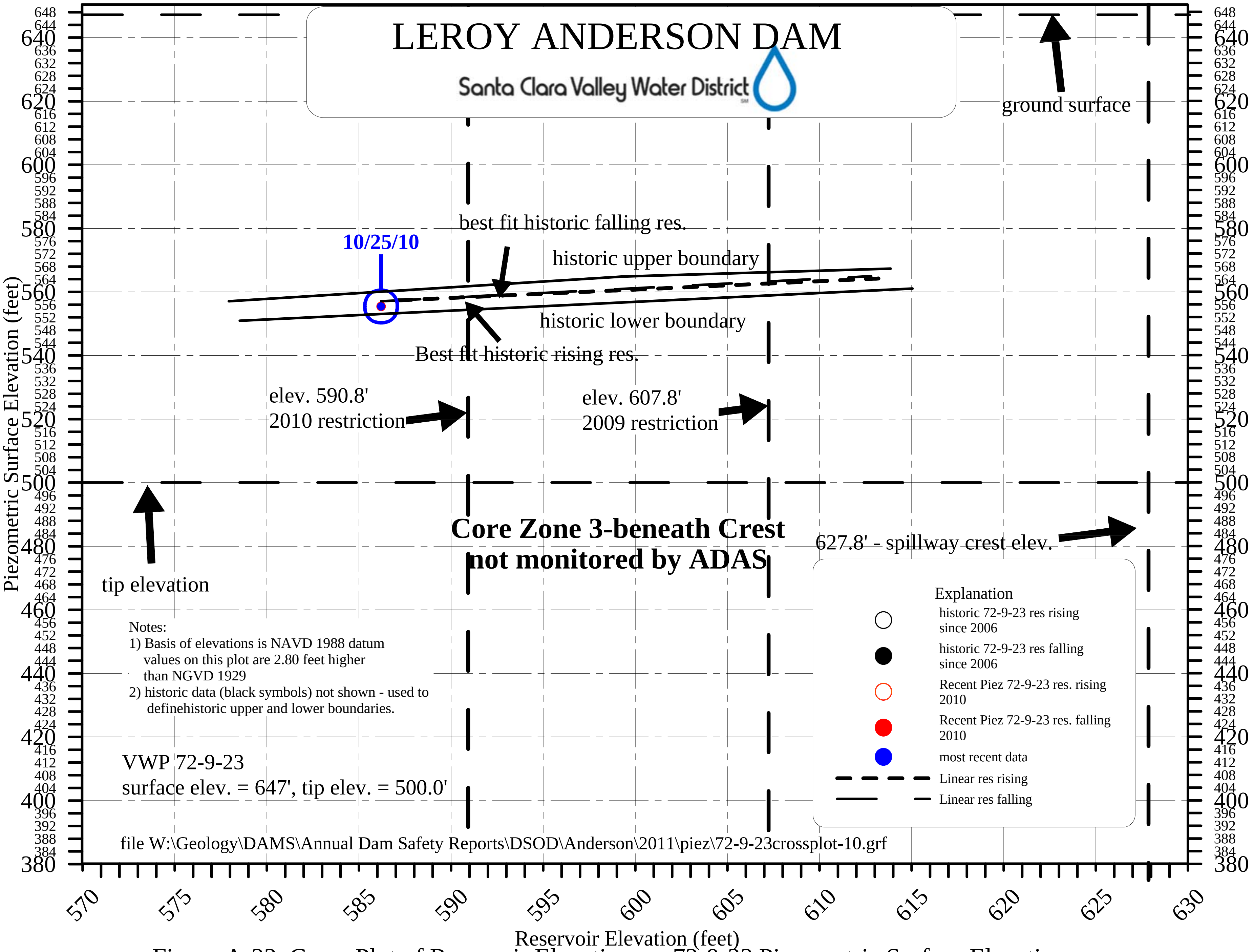
Figure A-21. Cross-Plot of Reservoir Elevation vs. 72-9-21 Piezometric Surface Elevation



Notes:
1) Basis of elevations is NAVD 1988 datum
values on this plot are 2.80 feet higher
than NGVD 1929
2) historic data (black symbols) not shown - used to
definehistoric upper and lower boundaries.

file W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\Anderson\2011\piezdata&plots\72-9-22crossplot-10.grf

Figure A-22. Cross-Plot of Reservoir Elevation vs. 72-9-22 Piezometric Surface Elevation



Notes:
1) Basis of elevations is NAVD 1988 datum values on this plot are 2.80 feet higher than NGVD 1929
2) historic data (black symbols) not shown - used to definehistoric upper and lower boundaries.

Figure A-23. Cross-Plot of Reservoir Elevation vs. 72-9-23 Piezometric Surface Elevation

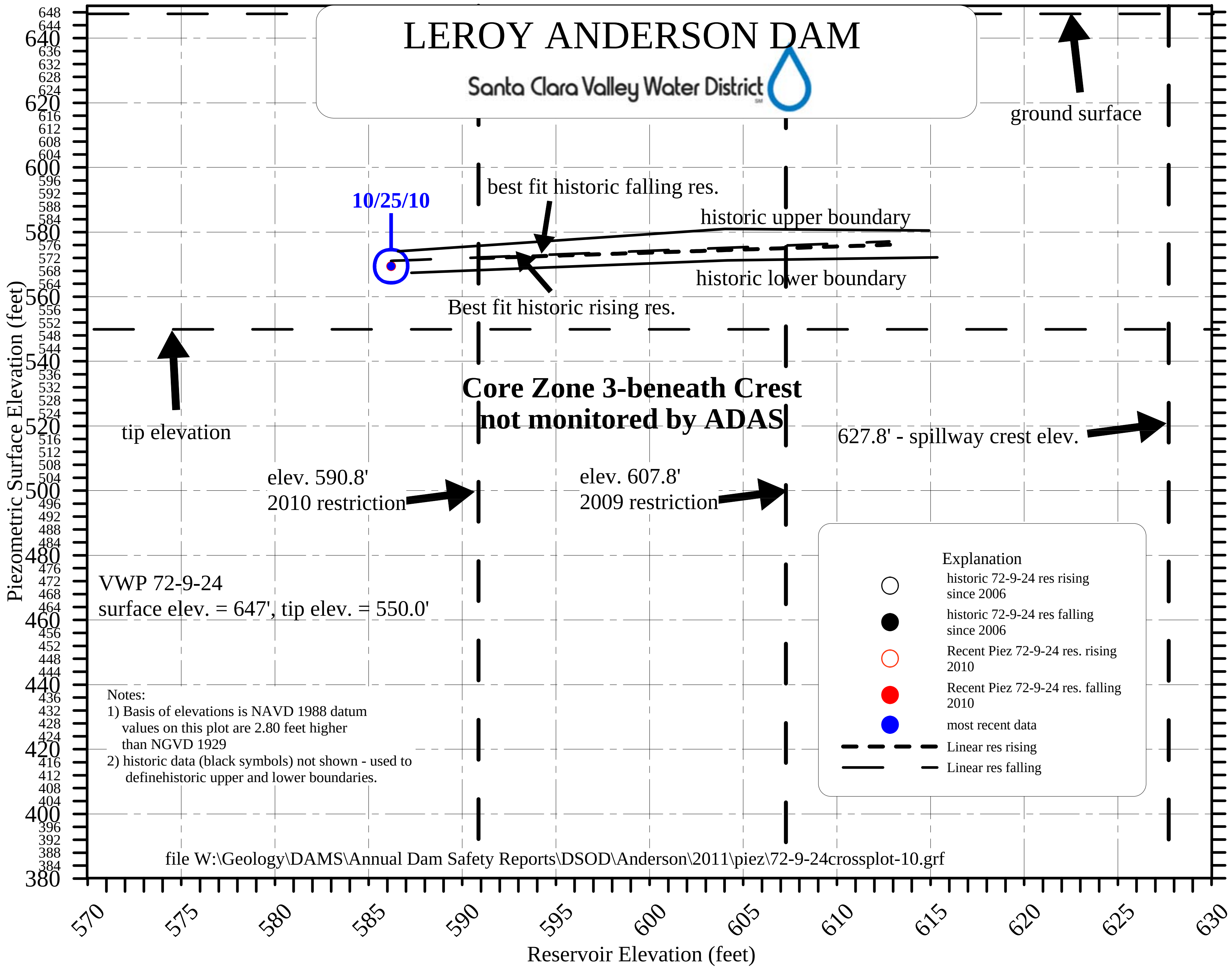
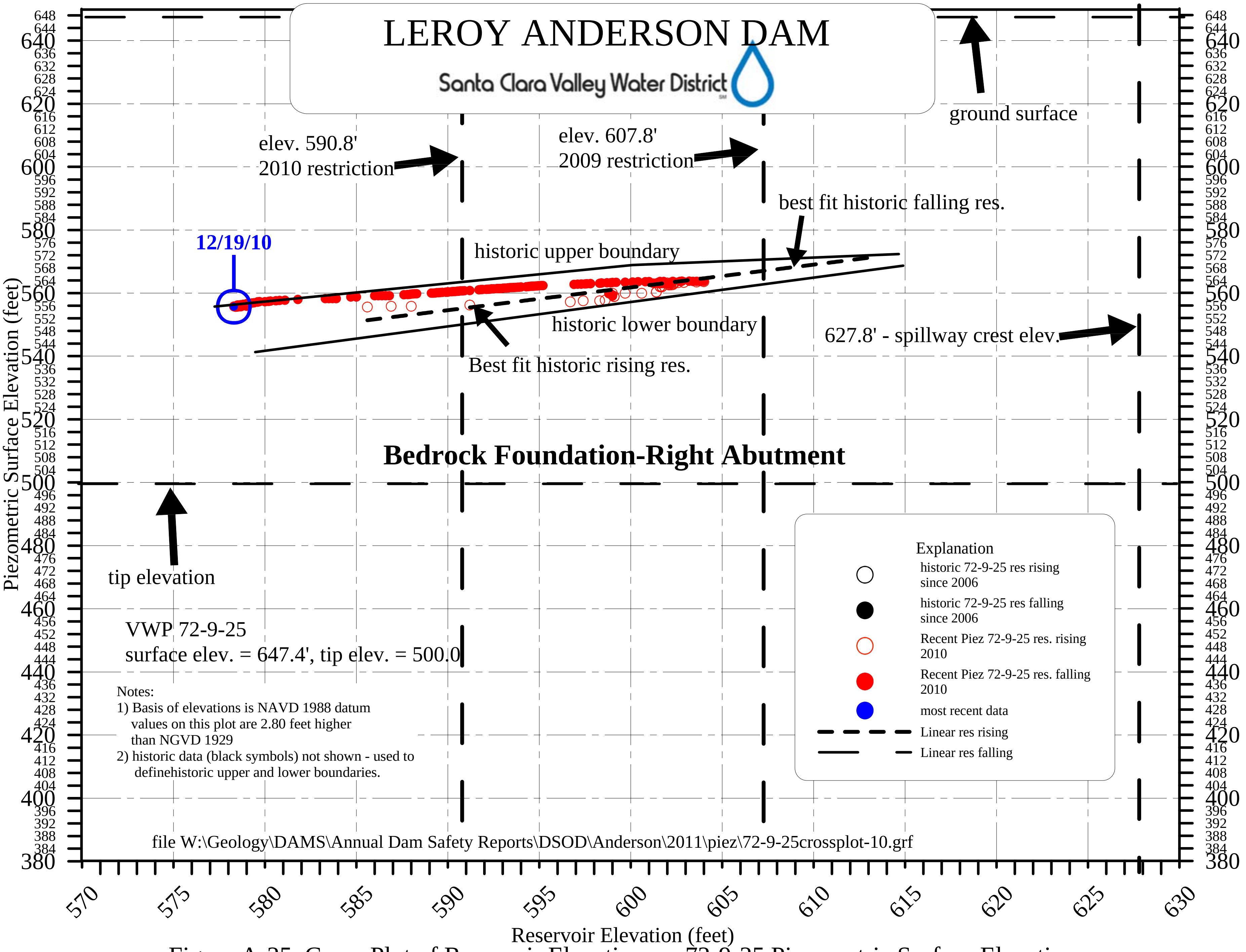


Figure A-24. Cross-Plot of Reservoir Elevation vs. 72-9-24 Piezometric Surface Elevation



Notes:
1) Basis of elevations is NAVD 1988 datum values on this plot are 2.80 feet higher than NGVD 1929
2) historic data (black symbols) not shown - used to definehistoric upper and lower boundaries.

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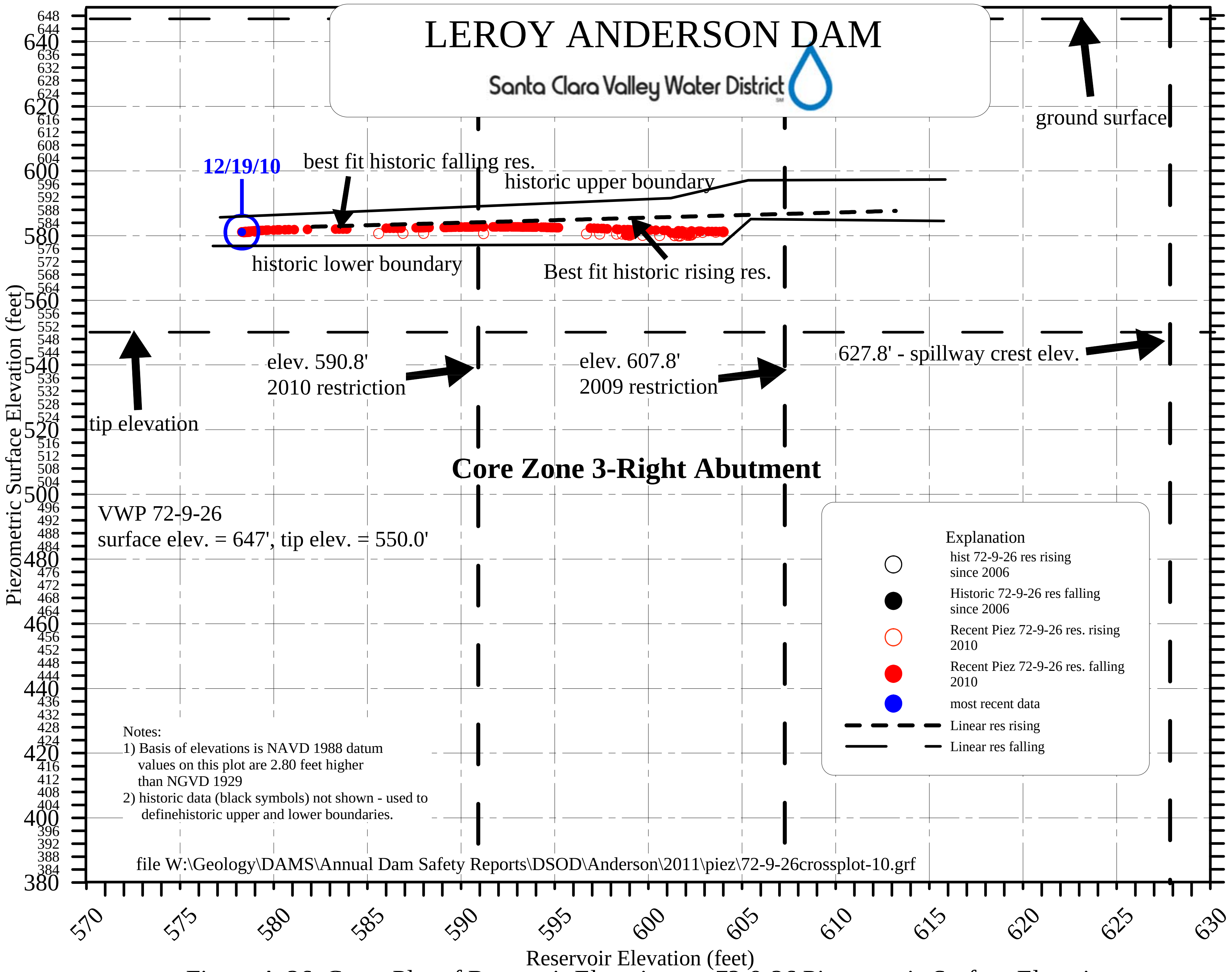
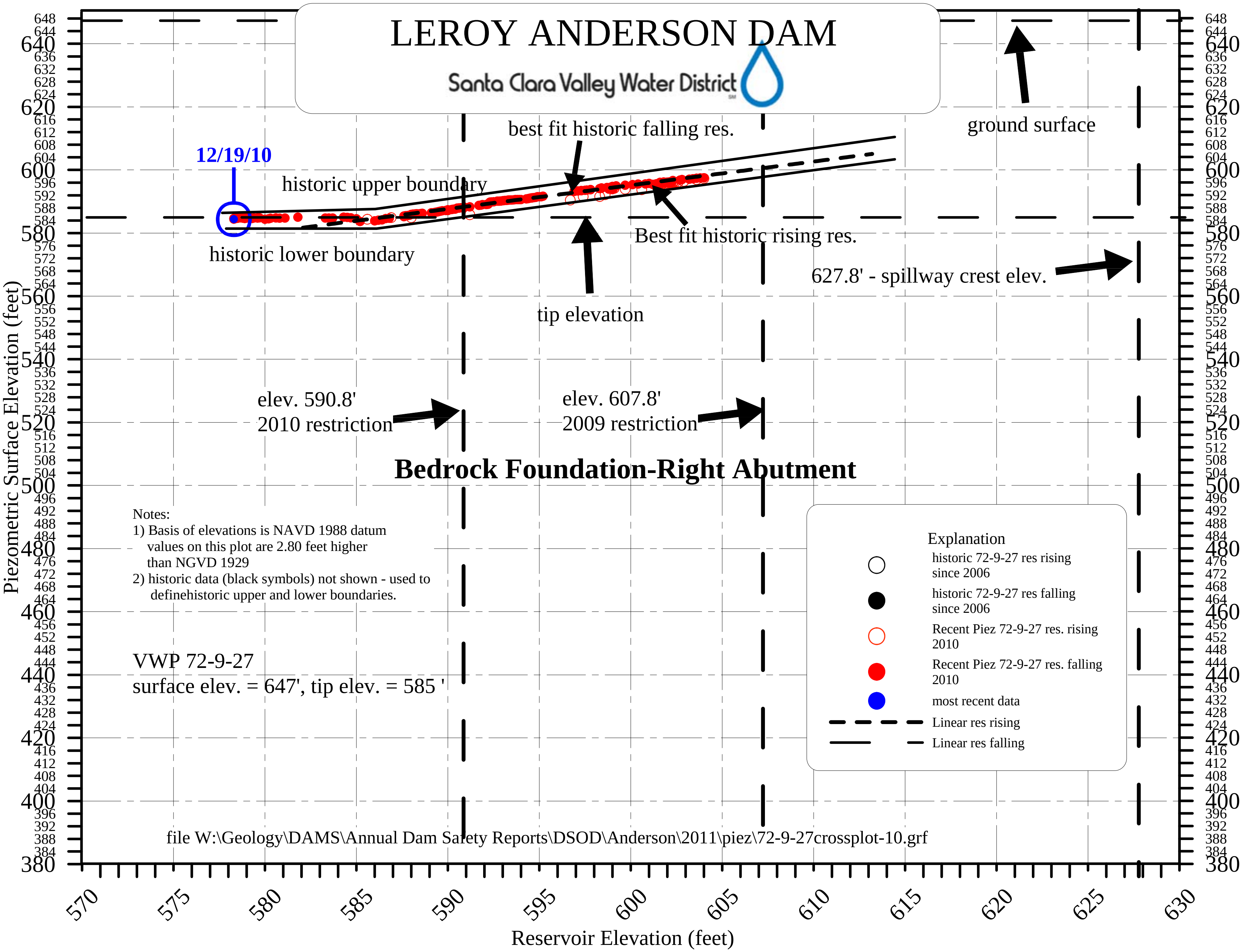
Figure A-25. Cross-Plot of Reservoir Elevation vs. 72-9-25 Piezometric Surface Elevation



Notes:
1) Basis of elevations is NAVD 1988 datum
values on this plot are 2.80 feet higher
than NGVD 1929
2) historic data (black symbols) not shown - used to
definehistoric upper and lower boundaries.

file W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\Anderson\2011\piez\72-9-26crossplot-10.grf

Figure A-26. Cross-Plot of Reservoir Elevation vs. 72-9-26 Piezometric Surface Elevation

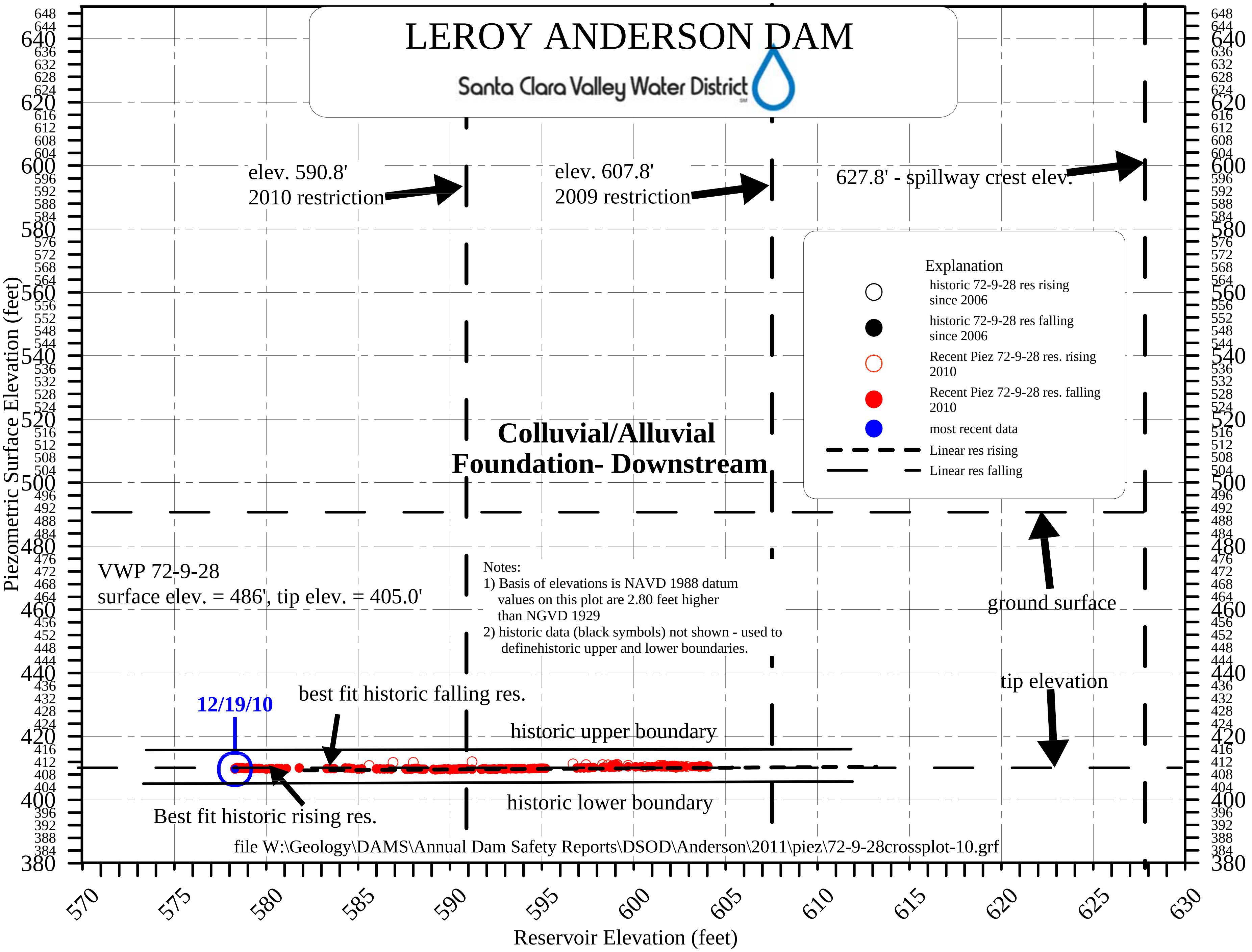


Notes:
1) Basis of elevations is NAVD 1988 datum values on this plot are 2.80 feet higher than NGVD 1929
2) historic data (black symbols) not shown - used to definehistoric upper and lower boundaries.

VWP 72-9-27
surface elev. = 647', tip elev. = 585 '

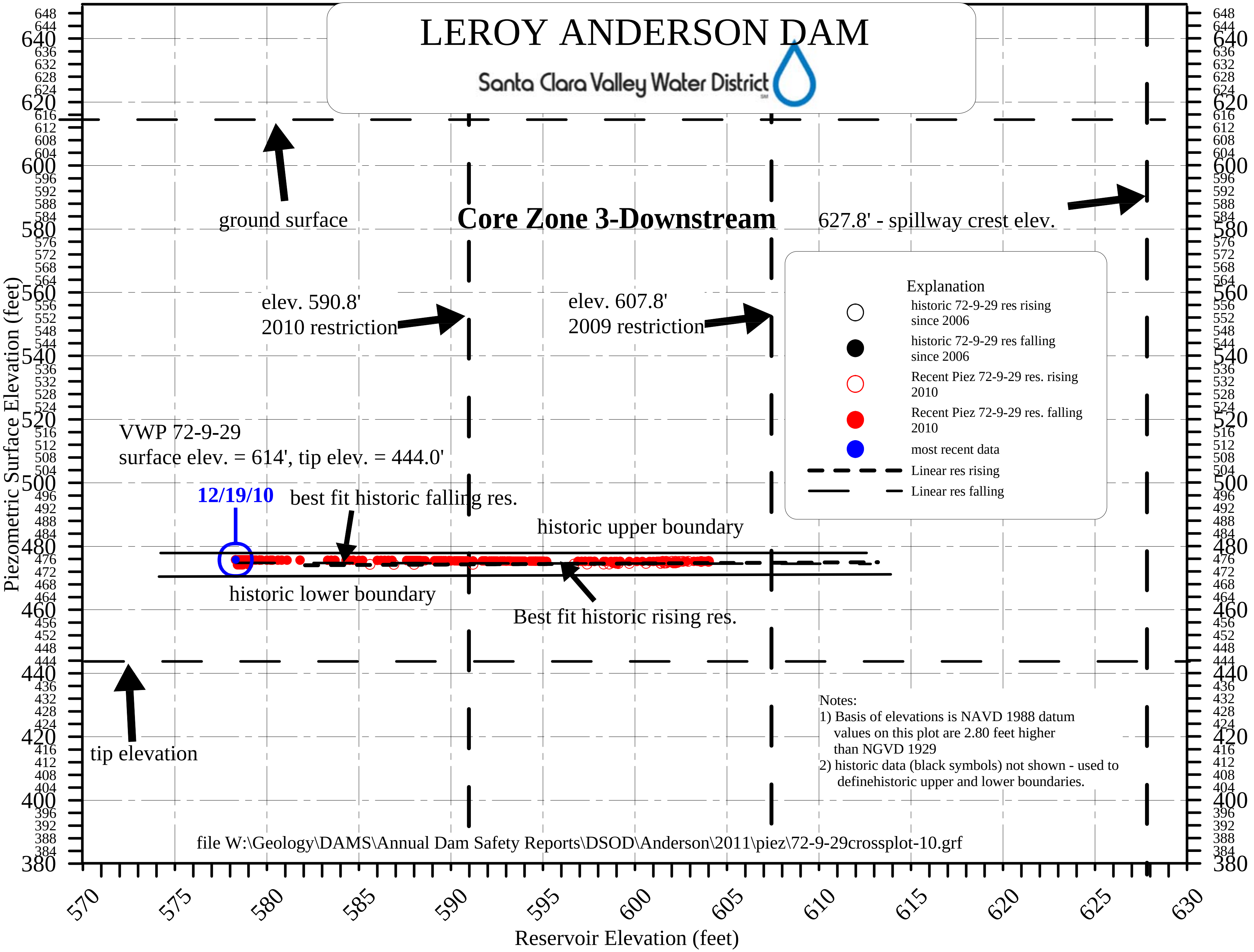
file W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\Anderson\2011\piez\72-9-27crossplot-10.grf

Figure A-27. Cross-Plot of Reservoir Elevation vs. 72-9-27 Piezometric Surface Elevation



Notes:
1) Basis of elevations is NAVD 1988 datum values on this plot are 2.80 feet higher than NGVD 1929
2) historic data (black symbols) not shown - used to definehistoric upper and lower boundaries.

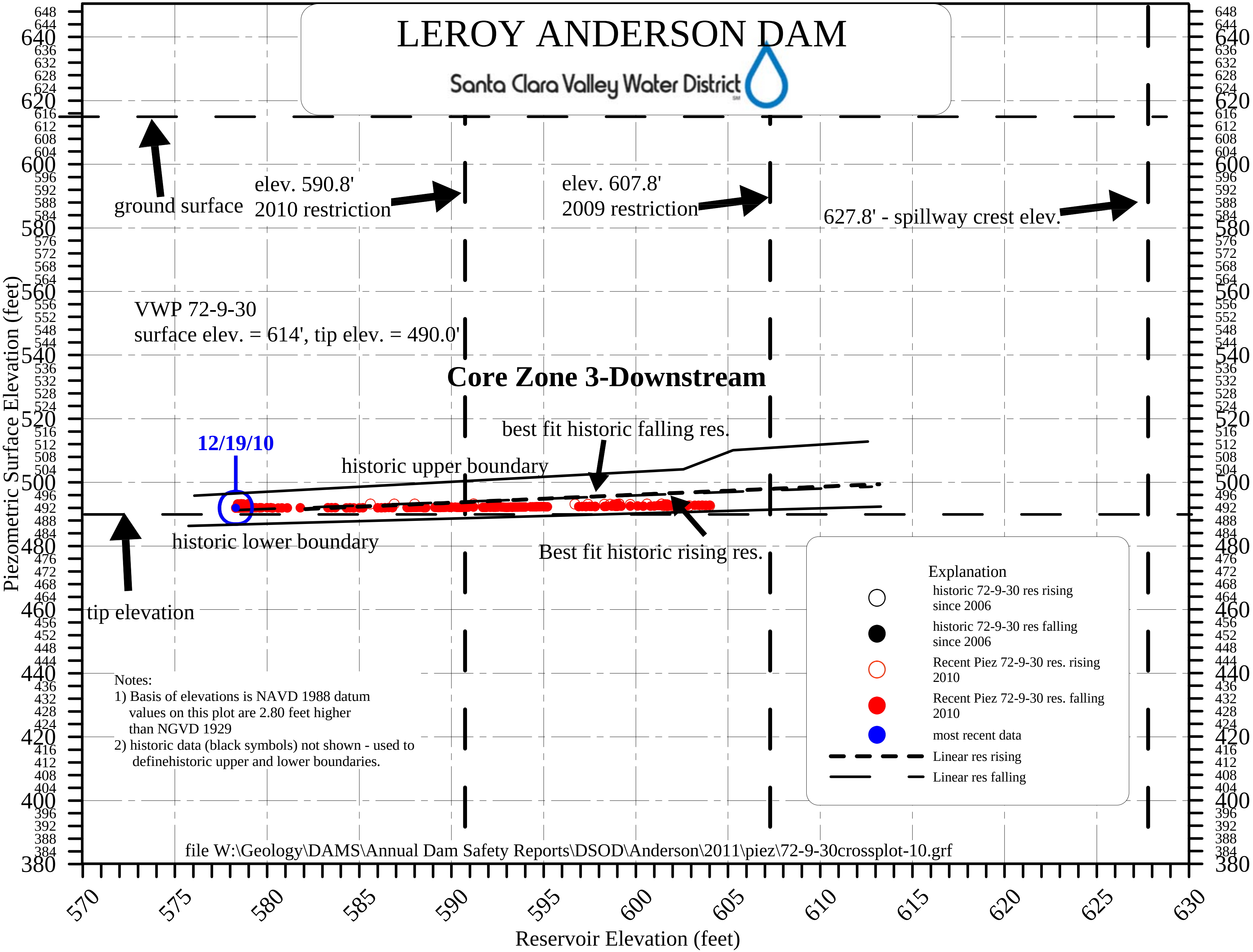
Figure A-28. Cross-Plot of Reservoir Elevation vs. 72-9-28 Piezometric Surface Elevation



Notes:
1) Basis of elevations is NAVD 1988 datum
values on this plot are 2.80 feet higher
than NGVD 1929
2) historic data (black symbols) not shown - used to
definehistoric upper and lower boundaries.

file W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\Anderson\2011\piez\72-9-29crossplot-10.grf

Figure A-29. Cross-Plot of Reservoir Elevation vs. 72-9-29 Piezometric Surface Elevation



Notes:
1) Basis of elevations is NAVD 1988 datum values on this plot are 2.80 feet higher than NGVD 1929
2) historic data (black symbols) not shown - used to definehistoric upper and lower boundaries.

file W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\Anderson\2011\piez\72-9-30crossplot-10.grf

Figure A-30. Cross-Plot of Reservoir Elevation vs. 72-9-30 Piezometric Surface Elevation

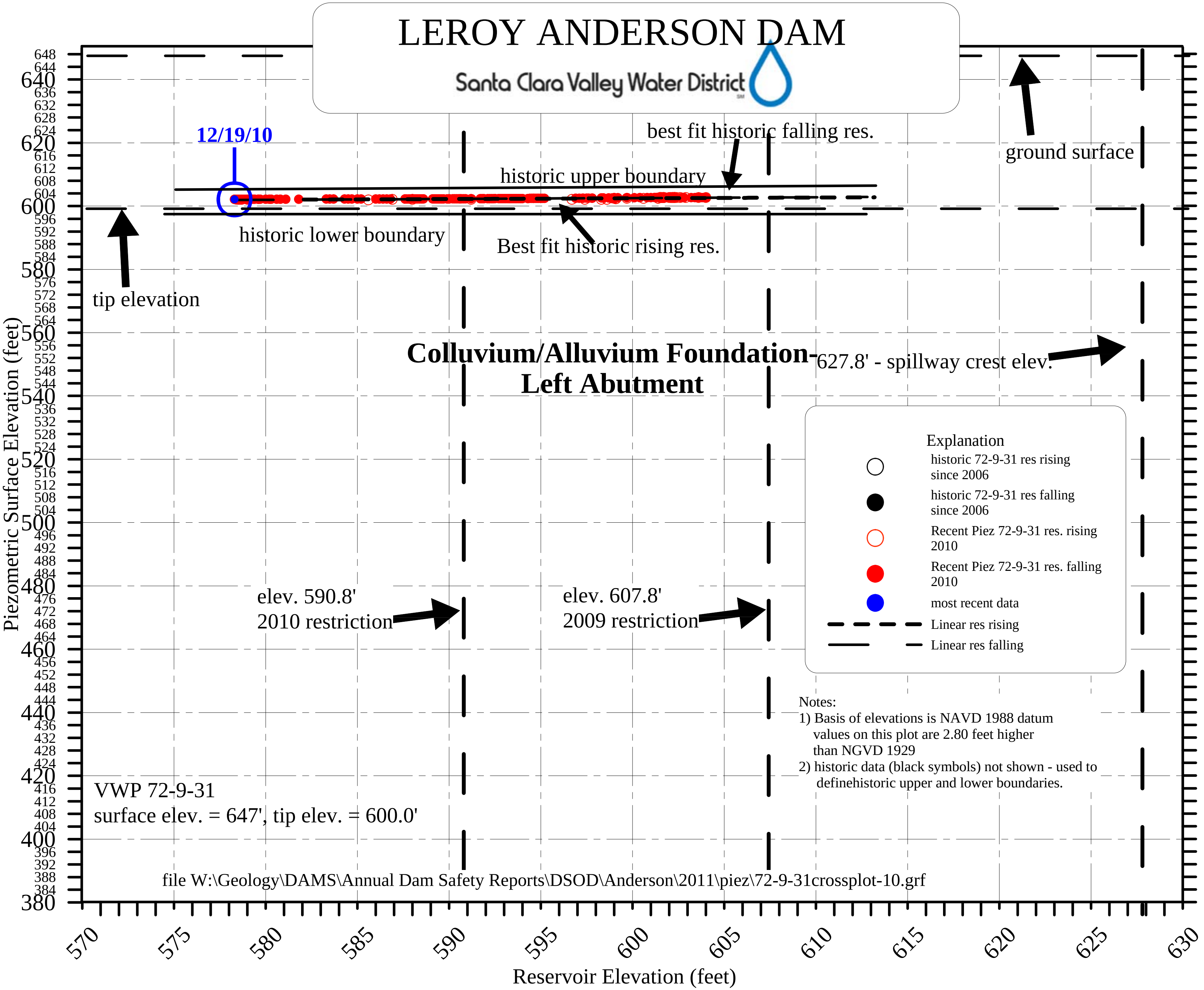
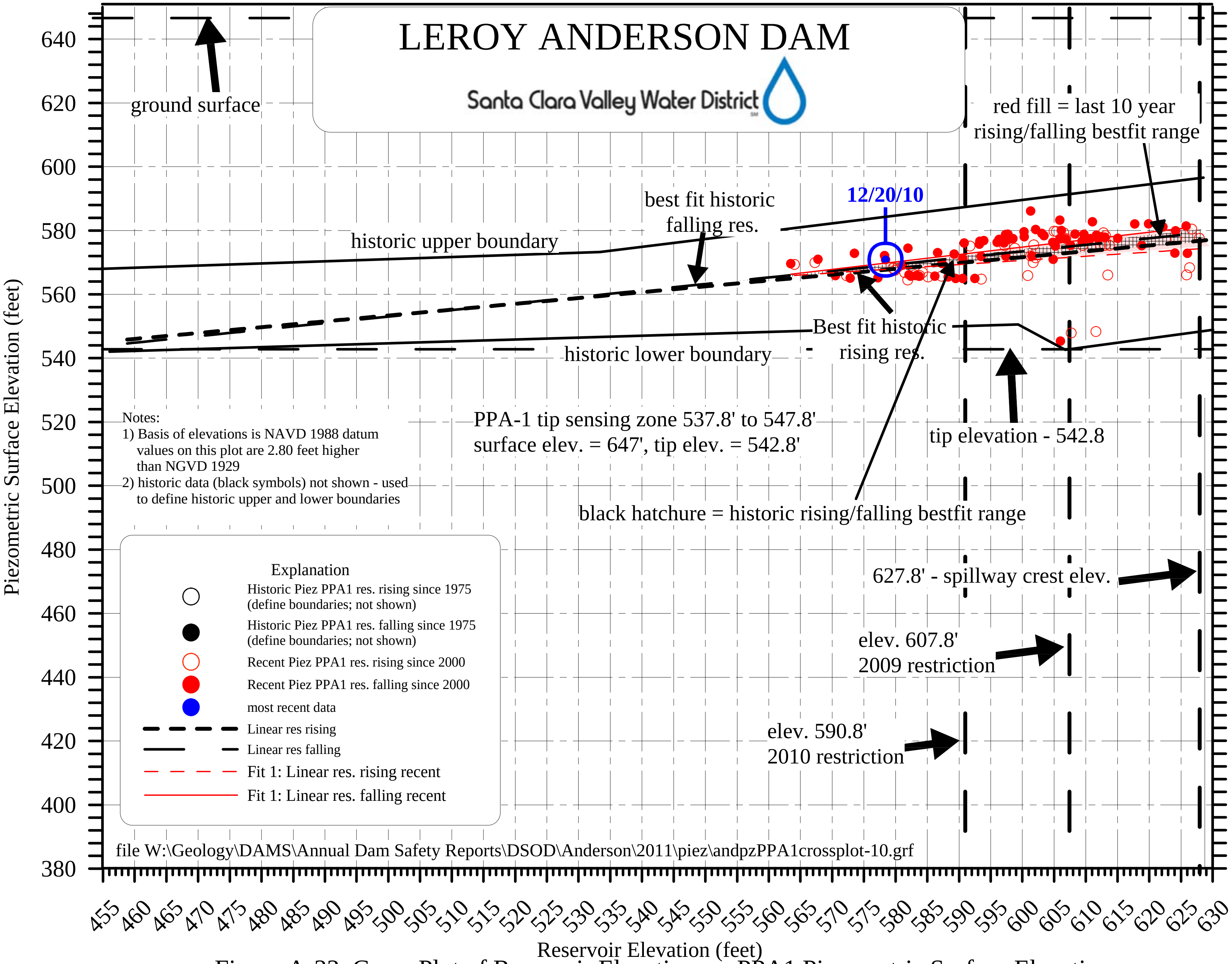


Figure A-31. Cross-Plot of Reservoir Elevation vs. 72-9-31 Piezometric Surface Elevation

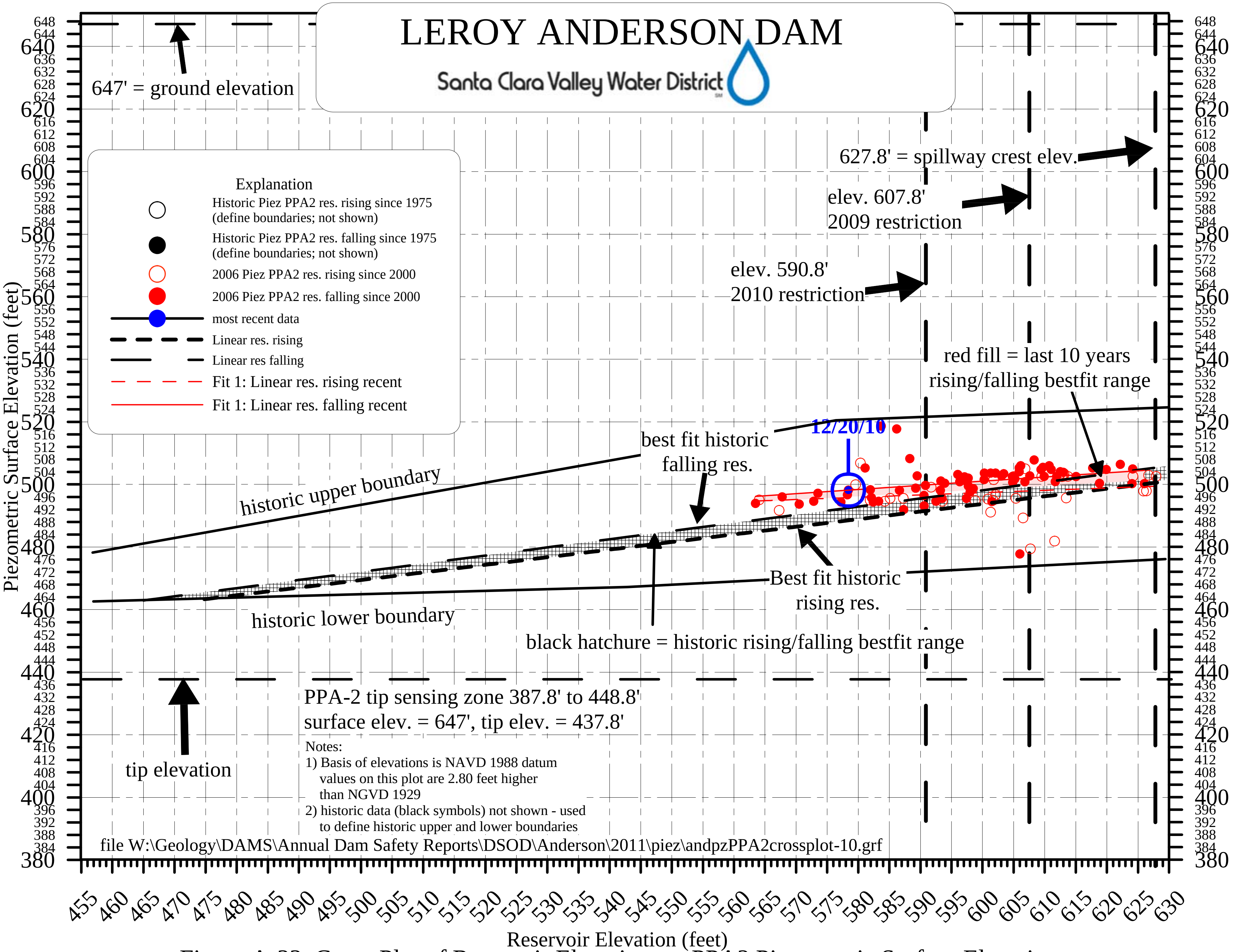


PPA-1 tip sensing zone 537.8' to 547.8'
surface elev. = 647', tip elev. = 542.8'

Notes:
1) Basis of elevations is NAVD 1988 datum values on this plot are 2.80 feet higher than NGVD 1929
2) historic data (black symbols) not shown - used to define historic upper and lower boundaries

file W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\Anderson\2011\piez\andpzPPA1crossplot-10.grf

Figure A-32. Cross-Plot of Reservoir Elevation vs. PPA1 Piezometric Surface Elevation



Notes:
1) Basis of elevations is NAVD 1988 datum values on this plot are 2.80 feet higher than NGVD 1929
2) historic data (black symbols) not shown - used to define historic upper and lower boundaries

file W:\Geology\DAMS\Annual Dam Safety Reports\DSOD\Anderson\2011\piez\andpzPPA2crossplot-10.grf

Figure A-33. Cross-Plot of Reservoir Elevation vs. PPA2 Piezometric Surface Elevation

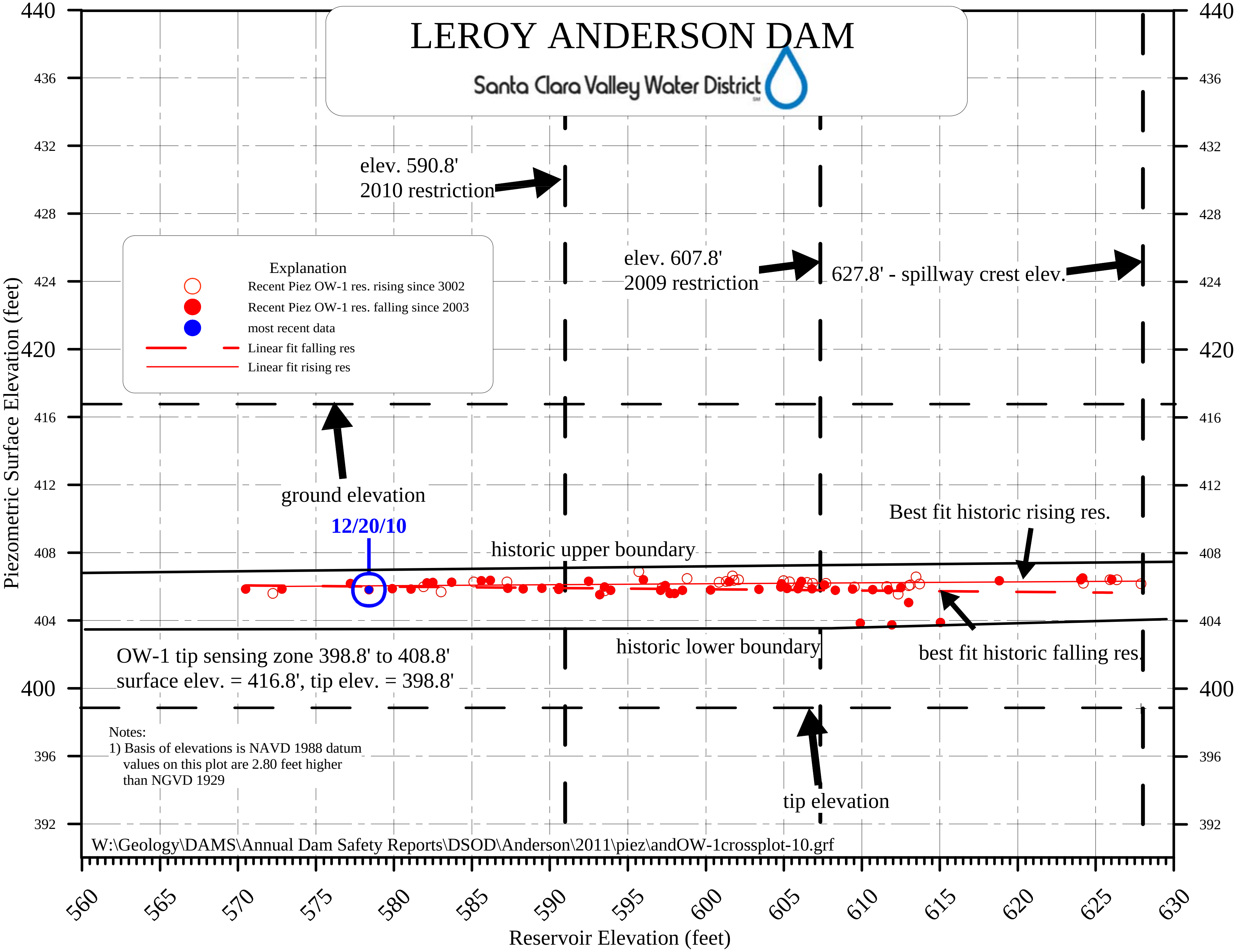
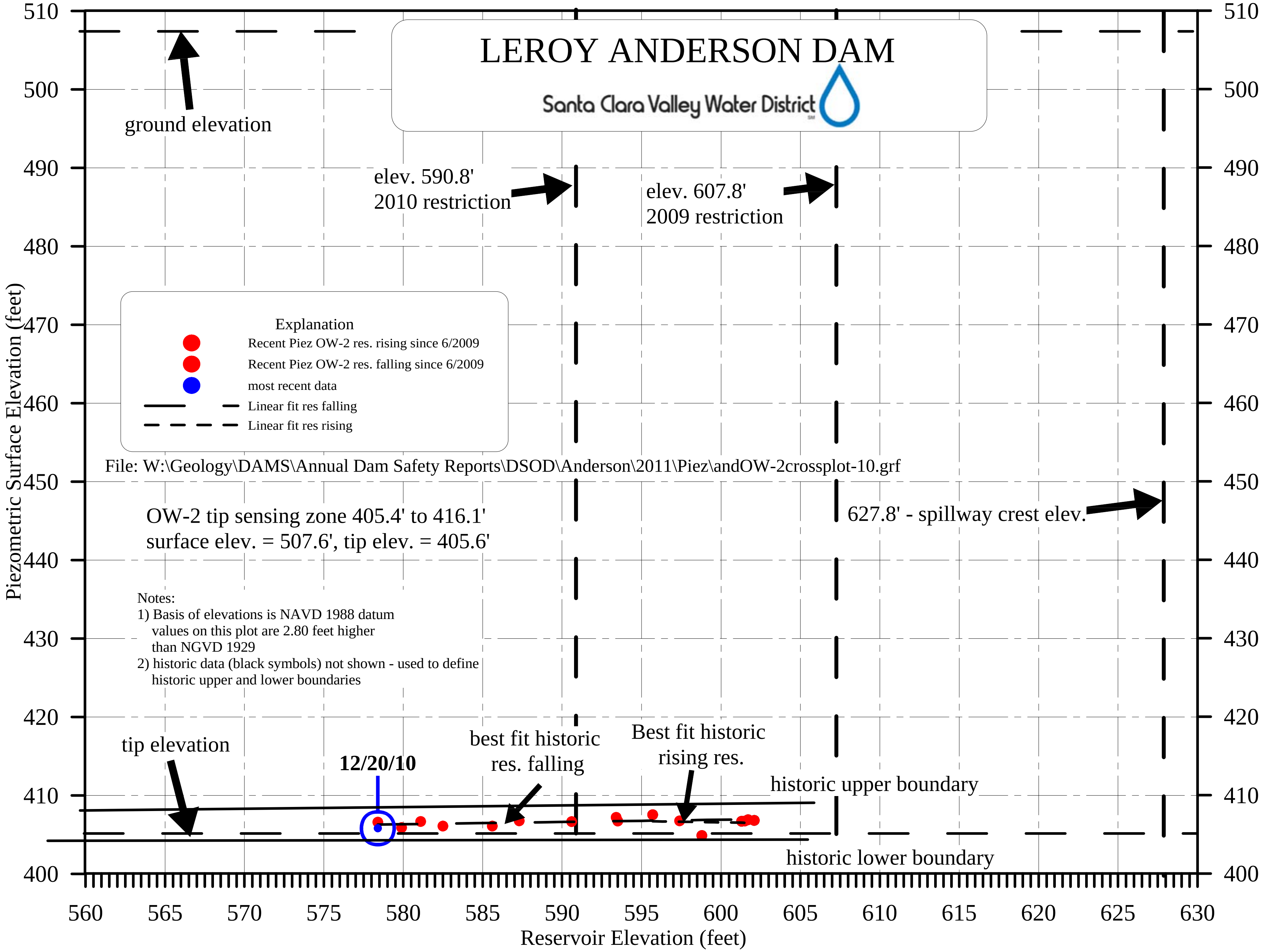


Figure A-34. Cross-Plot of Reservoir Elevation vs. OW-1 Piezometric Surface Elevation



OW-2 tip sensing zone 405.4' to 416.1'
surface elev. = 507.6', tip elev. = 405.6'

Notes:
1) Basis of elevations is NAVD 1988 datum values on this plot are 2.80 feet higher than NGVD 1929
2) historic data (black symbols) not shown - used to define historic upper and lower boundaries

Figure A-35. Cross-Plot of Reservoir Elevation vs. OW-2 Piezometric Surface Elevation

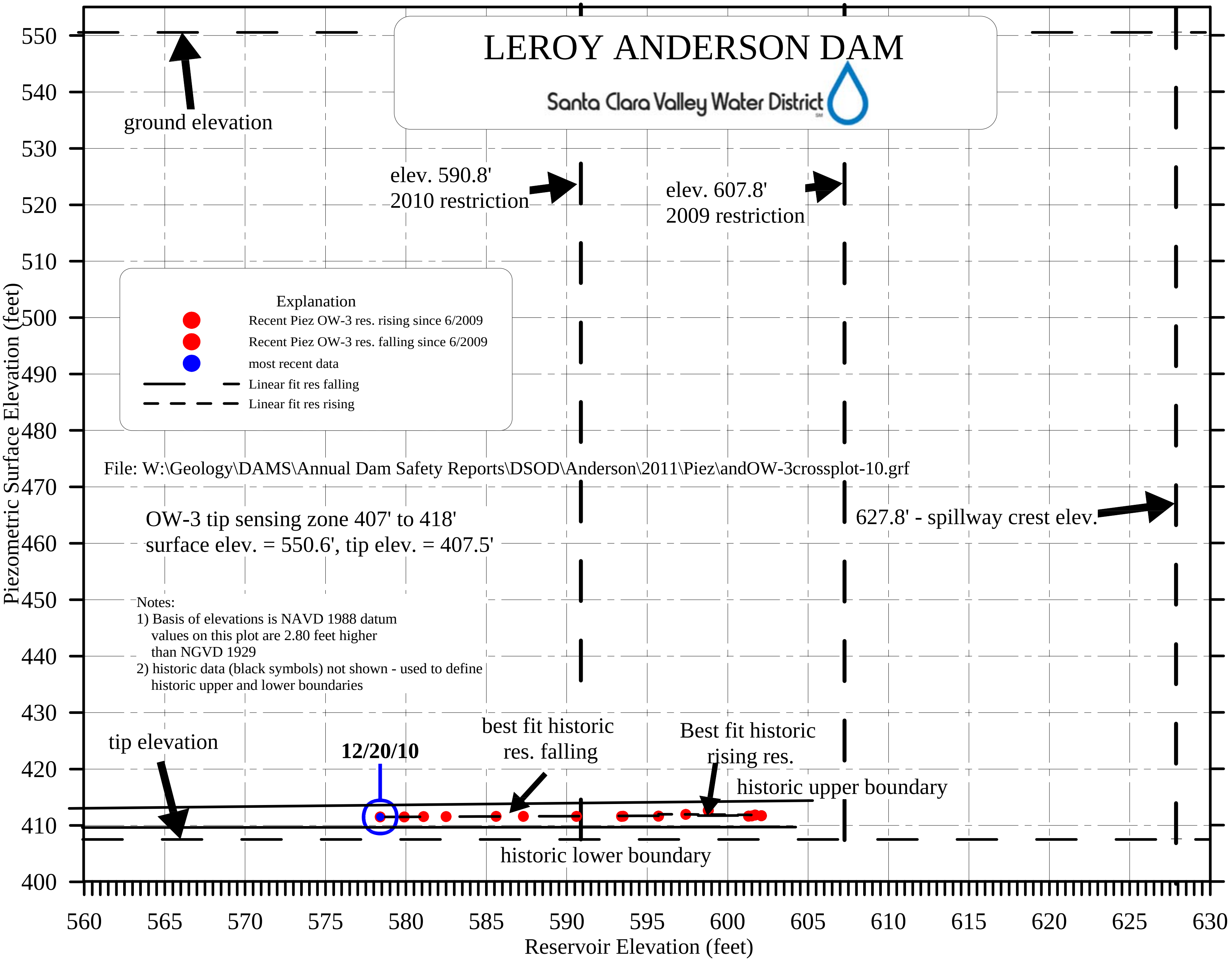
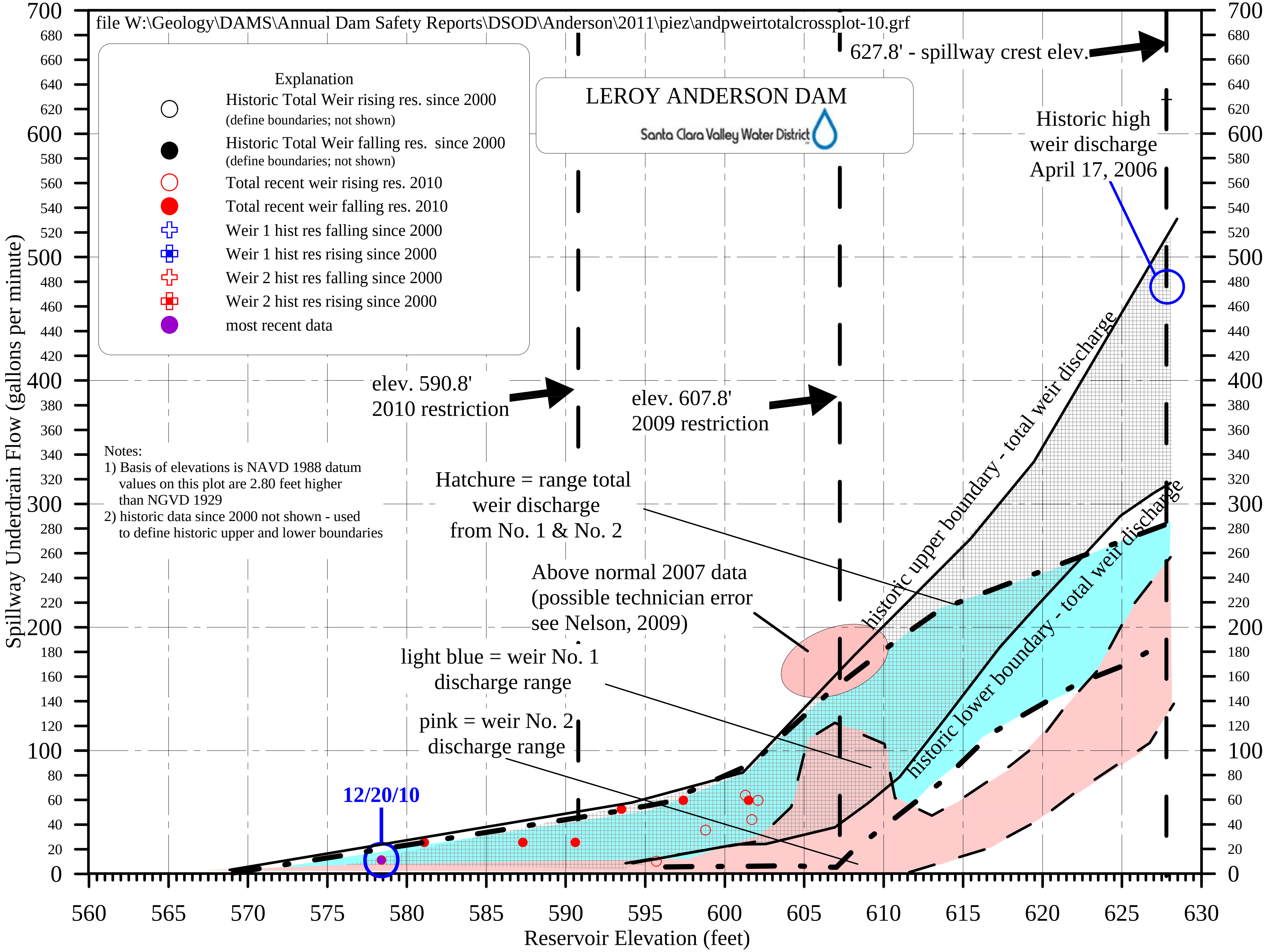


Figure A-36. Cross-Plot of Reservoir Elevation vs. OW-3 Piezometric Surface Elevation



Notes:
1) Basis of elevations is NAVD 1988 datum values on this plot are 2.80 feet higher than NGVD 1929
2) historic data since 2000 not shown - used to define historic upper and lower boundaries

Figure A-37. Cross-Plot of Reservoir Elevation vs. Spillway Weir Discharge, gpm